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SCIENCE IN INDIA

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Dedicated

to

my beloved mother

CONTENTS

		Page
	Preface	vii
1.	The ancient India and the dawn of Science ...	1
2.	An early sunset of Indian Science — the socio-political factors	19
3.	Revival of scientific studies in India ...	32
	[Chronology of one hundred years' progress in India (1757-1857)] ...	46
4.	Mahendralal and the contemporary movement for Science in India ...	49
5.	Rev. Father Lafont of St. Xavier's Collège ...	67
6.	Pioneer scientists in modern India ...	85
7.	Religion and Science in the Indian context ...	99
8.	Quo Vadis Indian Science ...	119
	Select Bibliography ...	149
	Index ...	153

PREFACE

The history of science in India has been a neglected field of study. Late Dr. Kalidas Nag, the eminent historian once remarked to the author, that in our country very few historians have studied science and very few scientists have cared for the history of science.

Science has uniquely influenced the human civilisation. J. D. Bernal and other scholars have vividly pointed out how the scientific discoveries and technological innovations have brought in radical economic and political changes. Thus, the human history need not be viewed in the contexts of wars and invasions alone. The history of Indian civilisation written in the frame-work of religious movements and military warfare alone can not completely explain the glory of the Gupta period, the mediaeval decadence and the resurgence since the nineteenth century. The role of science in different epochs of Indian history has been vitally important and is therefore a fit subject for detailed studies.

There are some excellent treatments on the developments of different branches of science in ancient India. However, there is considerable scope to analyse these developments in the socio-political contexts. The first two articles in this book contain an analysis of the growth of Indian science till the 8th century and its decay thereafter. For the sake of printer's facility, diacritical marks have been avoided in these two articles.

Modern science had its first footsteps in India along with the advent of British supremacy in the country. 'Revival of scientific studies in India' depicts the spreading of scientific education in the country during the late eighteenth and early nineteenth century.

The initiation of modern scientific education and research in India has been indissolubly linked with the names of Mahendralal Sircar and Father Lafont. The fourth and the fifth articles describe apart from the biographical details of these two pioneers, the contemporary movement of Indian science during the latter half of the nineteenth century. In the sixth article, the readers shall find a not-too-technical discussion on the contributions of the pioneering scientists of our country, during the first half of the twentieth century.

Religion and Science are the two important cultural elements in human civilisation. Unfortunately, there exists an unjustified notion that these two cultures are irreconcilable and that religious feeling inhibits scientific thinking. Arguments have been given in the seventh article in favour of a view-point that reconciliation of the two apparently contradictory values is not only possible but also desirable, particularly in the Indian context.

In the last article, the current ominous trends of the Indian science are portrayed in what some critics may consider as dark colour. However, the main purpose of this concluding article is to emphasize that science can flourish only in the proper socio economic background under optimum motivational factors and with suitable ideological environment. If we can cure the maladies which exist in our national life, then Indian science may yet attain the desired pinnacle of glory.

In this book, the word 'science' has been used in the wide context embracing 'technology' as well. The treatments of the topics are far from exhaustive and some of the view-points may appear as controversial. However, the very purpose of this book is precisely to evoke some critical thinking and encourage scholastic studies on the subject so that the readers may eventually reach their own conclusions with regard to the questions and problems enunciated in this

book. To help the readers in this direction, a select bibliography has been given at the end, which again is not exhaustive. It is hoped by the author that in the near future, sufficient number of scholars equally versed in history and science, would dedicate themselves towards a comprehensive and critical compilation of history of science in India.

The first two and the fifth articles are enlarged versions of the originals published in 'Modern Review'. The author is grateful to the publishers of 'Modern Review' for allowing incorporation of the articles in this book. Considerable help was received from Fathers P. Turmes and A. Huart S. J. of St. Xavier's College, Calcutta in collecting biographical materials on Rev. Father Lafont.

The author recalls with deep gratitude the valuable inspiration received from Late Dr. Kalidas Nag. Several colleagues at the Indian Institute of Technology, Kanpur, viz., Dr. K. N. Upadhyaya, Dr. S. K. Mukherji, Dr. H. S. Ray, Dr. A. Ghosh and others as well as Mr. N. K. Sinha, an old friend helped the author considerably by offering pertinent criticisms and suggestions. Sincere thanks are offered to all of them.

Lastly, the author recalls the encouragement and inspiration received from his wife, Sulekha in writing this book.

Author

THE ANCIENT INDIA AND THE DAWN OF SCIENCE

Neither the East nor the West can claim a monopoly in the history of scientific progress. In this second half of the twentieth century, the developed as well as the developing countries are surging forward in science, and contributing their mite in the joint endeavour. So also in the past, Asia's and particularly India's role in scientific advancement was remarkable. The growth of modern science in Europe would have been hardly possible without the background of pioneering contributions from China, Arabian countries and India, well up to the 12th century A.D.

It is difficult to retrace the evolutionary stages of human endeavour in science. The capacity to accurately observe, infer, experiment and interpolate existed in human mind even at the time of the classical discovery of fire. Since then, man has only sharpened his intellect, amassed useful information and acquired more fruitful techniques. To defend himself against the wild animals and vagaries of nature, and to satisfy the needs of food and clothing for himself and his kith and kin, were the basic urges which led man to improve his techniques; this process is far from complete even to-day.

The wise men of ancient India (also of Egypt and China) developed the faculty of speculation, with which they laid the foundations not only of theology and primitive religion but also of scientific thinking. The observation of heavenly bodies and nature inspired some of the thinkers towards religious fervour; the more pragmatic ones however utilised their careful observations for weather prediction, navigation and agriculture.

There are reasons to believe that the pre-vedic civilisations of Mohenjo-daro and Harappa (4000-3000 B.C.) were

quite advanced in arts and crafts. The discovered ruins clearly reveal remarkable feats achieved in drainage and other civil engineering works. The people developed a system of pictographic writing. They used copper, bronze, burnt bricks, ceramics and 'weights. Since their scripts have not been fully deciphered, we can not say any thing more about the ingenuity of the people of Mohenjo-daro and Harappa.

In any case, when the Aryans invaded the Indus valley sometimes around 1500 B.C., they found in India a suitable background for fruitful pursuit of science. The Vedas : Rig, Sama, Yajur and Atharva (1500-1000 B.C.) represented the very best in speculative thinking apart from containing numerous references on drugs, diseases and stars. Kanad and Kapil, the vedic philosophers, referred to five "immutable " elements which were constituents of all matter. They also developed the concepts of *anu* (molecule) and *paramanu* (atom). Kanad proposed the undulatory theory for the propagation of sound and made the speculation that light and sound waves are only different manifestation of the same energy. Samkhya, Rig Veda etc, are full of philosophical enquiries as regards the universe, how it was created, how life came on to this earth and so on.

Rig Veda describes the sun's annual course as "twelve-spoked wheel" corresponding to the twelve signs of zodiac. On this basis, one year was divided into twelve months, each of 30 days. Atharva Veda refers to an intercalary thirteenth month (once in five years) to bridge the gap between the civil and the tropical year. Yajur Veda refers to twenty seven *nakshatras* or constellations to describe the movements of the moon. The Satapatha Brahmana states that one year consists of 10,800 moments, each 'moment' being the thirtieth part of the day. Gradually, an elaborate luni-solar astronomical calendar was devised and described in Jyotisha-vedanga (300 B.C.).

The authors of Rig Samhita were accurate observers of winter and summer solstices and solar and lunar eclipses. Even in that early age of rituals and dogmatic religious beliefs, a statement was made in the Atharva Samhita to the effect that though the solar eclipse is popularly believed to be due to a monster called Rahu, the more likely cause is the interposition of the moon between the sun and the earth. Expressions of scientific opinion contrary to religious beliefs were common in the vedic ages ; the fact that there were scarcely any religious persecution bears testimony to the spirit of tolerance in Hindu culture. Free contact with and assimilation from the Persian and Babylonian civilisation particularly after Alexander's invasion (325 B.C.) further point towards the dynamic civilisation in India.

The ancient Hindus were also interested in geometry of ritual altars for sacrificial fire. The Kalpa-sutra, a ritual vedic text had an important supplementary, Sulya-sutra (rules of the thread or 'measuring line') devoted to the topic. Baudhayana, Apastamba and Katyayana schools developed methods of construction of squares and rectangles, relation of the diagonals to the sides, equivalence of circles with rectangles and squares in terms of area etc. The discovery of the geometrical theorem stating that the square on the diagonal of a rectangle equals the sum of the squares on the two sides in area, is usually attributed, without any justificatoin, to the Greek Savant Pithagorus. However, the following statement is found in several places in Satapatha Brahmana and Sulyasutra :

" The transverse chord of a rectangle produces, by the construction of a square on itself, what the length and the breadth produce separately."

The decimal system of number, perfected later by Aryabhata was in vogue during the vedic ages. Large num-

bers upto 108 are referred to in many ancient Hindu scriptures.

In the rural academic environments, the ancient Indians had an ideal opportunity to study different kinds of plants and their medicinal properties. The science of medicinal plants was developed for the first time in India by Atreya, the physician and the teacher at the University of Taksashila or Taxila on the Jhelum (sixth century B.C.). His students, Jivaka (a contemporary of the Buddha) Agnivesa and Bhela and later Charaka as well as Susruta of Varanasi further developed plant therapy, medicine and surgery.

It was at Taxila, that the scientists in Alexander's army first made contact with the Hindu sages (325 B.C.). There is striking similarity between the early Indian and Greek medical texts. The concepts of 'ojas' (energy), 'rasa' (vital juice), 'prana' (breath) affected by 'tridhatu' or the three elements of fire, water and wind, the bile, the mucus etc., were developed in India and then propagated in Greece. Plato's medical treatise 'Timaeos' contains ideas quite uncommon with the contemporary or earlier Greek medical practice but strikingly resembling the Indian system at that time. Aristoxenes of Tarentum, a disciple of Aristotle reported that an Indian sage called on Socrates in Athens. The role of pepper, an Indian medicament, was described in the 'Diseases of Women', a part of the Hippocratic collection. Accounts of Megasthenes clearly reveal the Indian advancements in veterinary science during Chandragupta's reign (4th Century B.C.). Ashoka (3rd Century B.C.) consolidated peace and scientific progress in the domains of medicine, botany and civil works.

II

Before proceeding to discuss the Indian achievements in science during the post-Christian era, it would be worthwhile

to comment on the socio-economic factors in ancient India which played significant role in the growth of science.

The propagators of the vedic civilisation realised that division of labour was necessary for the optimum maintenance and growth of social structure*; this was a flexible concept though it resulted eventually in a rigid caste system. While some people had to specialise in technical arts, trade or administration, the job of advancement of knowledge was left and later restricted, to the Brahmanas. The educational system in the peaceful environment of forests, and the emphasis on 'plain living and high thinking', predestined the future growth of Indian science to a very large extent. To illustrate this point very briefly, the educational environments, isolated from the urban production centres were conducive to the growth of speculative and natural sciences but not of technical arts and crafts.

The age of epics, i.e. Ramayana and Mahabharata, heralded the rise of large states under absolute monarchs and a transition from rural to money economy. This transition was scarcely affected by the advent of Buddhism which influenced Indians in the religious and intellectual planes only.

Greek invasion of India brought about closer contact between the East and the West. The volume of international trade increased. Adventurous explorers helped in contact and concourse of Indian and Greek thoughts. All this promoted scientific and technological advancements in India, witnessed and described by the Greek, and later some Chinese travellers. The political situation was reasonably stable in the Maurya age and inspite of minor warfares (which completely died down towards the end of Ashoka's regime), the craftsmen were respected and merchants free to transact national and international trades on medicinal herbs, spices, silk and cotton etc. Kautilya described the economic conditions during the Maurya age in his famous treatise 'Ar-

thasastra'. Merchants were organised in guilds (sanghas and srenis). Free labourers 'worked on the basis of wage-contracts. Kautilya's code contains a whole section on labour-management relationship. Artisans and craftsmen were protected by the state against any cruelty from their employers, and the merchants compensated for loss of merchandise by theft or robbery. There is little wonder that in such ideal economic and political conditions, improvement of technical arts and crafts went on unabated. The advent of Buddhism helped the growth of Indian science in two indirect ways : (1) more educational institutions (e.g. Nalanda) were established (connected with monasteries, where people pursued astronomical and mathematical studies apart from theology) and, (2) evangelical spirit of the early Buddhists resulted in the spreading out of Indian culture in South Eastern, Central and Western Asia and assimilation of scientific knowledge possessed by communities in foreign countries.

III

The name of Susruta (of Varanasi), a contemporary of Atreya has been already mentioned. Susruta invented surgery. He was a true scientist and combined direct observation with reliable theory. The Samhita bearing his name contains description of several operations relating to cataract, hernia, caesarian section, plastic surgery and of several surgical instruments. The influence of his medical school on Indian science was pronounced for three centuries after Christ. This is indicated in the 4th century A.D. birch-bark Sanskrit manuscript, 'Navanitakam' (known as Bower manuscript) discovered by Mr. Bower in Kashgarh, Chinese Turkestan in 1889.

Charka, the court-physician to the Indo-scythian King, Kanishka (who reigned at Taxila during the end of 1st century or beginning of 2nd century A.D.) compiled his medical Samhita on the lines of Atreya and Agnivesa. He discussed various kinds of fevers, urinary affections, skin disease, epilepsy etc.

Charaka introduced logic into the critique of clinical criteria. Some of the comments found in Charak Samhita and Susruta Samhita reveal an amazing degree of objective and scientific thinking :

"To gain experience in surgery, one has to properly dress and dissect a corpse and minutely observe the anatomical details".

"The Vedas are valid but the consistent conclusions reached at by the wise men after accurate observations and experiments are no less valid".

Charaka and Susruta were not only experts in medicinal chemistry but also authors of several treatises on organic and inorganic compounds.

Indian 'materia-medica' based on herbs and minerals and compiled by Parasar, Jatukarna, Harit, Nagarjuna (of 2nd century A.D.), Vararuchi (Kalidas's contemporary) etc. was well known outside India. Much later, Indian texts on medicine were translated to the Arabic language, mainly through the efforts of Harun and Mansur (715 A.D.) who came in contact with the Indian thought. Haroun-Al-Raschid invited medical men to Bagdad and with their help, established an up-to-date hospital.

Similarly 'Yogasataka' translated into Kuchean language (8th century A.D.) was well known in Central Asia ; Amrtahrdaya, a medical work of Bhaishajyaguru, a Buddhist, was popular in Tibet and Mongolia ; Vagbhata's medical text, Ashtangasamgraha (6th century A.D.) was translated into Tibetan, and so on.

Mathematics and Astronomy in ancient India:

The growth of mathematical and astronomical sciences during the post-Christian era is the most glorious chapter in Indian science.

Varahamihira of the sixth century A.D. referred to five astronomical systems in vogue in India, in his Panchasiddhantika. The earliest viz., Paitamaha-siddhanta was written during the Saka period (78 A.D.) very much on the line of Jyotishavedanga. Vasishtha-siddhanta, probably compiled by Vishnuchandra strove to locate celestial bodies by dividing the sky into twelve parts of 30° each. Paulisa-siddhanta was written on the basis of work by Paul of Alexandria., It gave a method of determining the exact length of the day and a rough means of predicting eclipses. Romaka-siddhanta, written by Srisena was on the basis of Roman or Alexandrian sources.

Of the five, the most popular and surviving system has been the Surya Siddhanta which was compiled before 400 A.D. This compilation describes several astronomical instruments : the armillary sphere, simple gnomon, clepsydra etc.

Gnomon or 'Canku' was described as a staff (9″ inches) fixed at the centre of a circle. The shadow of the sun determined the time of the day at different seasons. A trigonometrical discussion was also furnished.

Clepsydra was described as a copper vessel 4-5″ inches high and of twice that width at the mouth. The vessel had hole of a 'gold-pin diameter' and was set in a basin of pure water which entered the vessel through the hole. The extent of filling was taken as a measure of the time during day and night. The sixtieth part of a day, 'ghati' or 'ghatika' (vessel) seems to be derived from the instrument.

In Surya-siddhanta, the Indian meridian was fixed to be at Ujjain, the centre of astronomical research. There are discussions on equinoxes, solstices, eclipses etc. The distance

between the moon and the earth was computed to be $30\frac{7}{13}$ times the diameter of the earth.

The most fascinating topic in Surya-siddhanta is the sine-table, which is the oldest in the world. The concept of semi-chord ('ardhajya' or bowstring in Sanskrit) was borrowed in Arabic ('jaib' or curved inlet) and then in mediaeval Latin (sinus or a curve) from which the final term 'sine' emerged. In the above text, there are references to cosine (Kotijya) and versed sine (Utkaramajya) also.

Some biased western scholars have claimed that all scientific thinking emerged from Greece and that what science the Indians had, they borrrowed. Jean Filliozat, the eminent French indologist has pin pricked the bubble of the above fantasy :

"The greatest historians of science have not always escaped from the inconvenience of knowing only one side of the matter. Paul Tannery, so famous for his studies on ancient mathematics, is an example. We know that the trigonometric sines is not mentioned by Greek mathematicians and astronomers, that it was used in India from the Gupta period onwards, that the Surya-siddhanta gives a table of sines, that the Arab astronomers knew them from their Indian contacts and passed them on to Europe in the twelfth century, when the work of al-Battani (858-929 A.D.) known as Albategnius in mediaeval Europe, was translated into Latin. . . . But Tannery, persuaded that the Indians could not have made any mathematical inventions, preferred to assume that the Indians knew of sines was sufficient proof that they must have heard about them from the Greeks......... If this is the way we are to argue, there was never any science other than Greek science, and the question whether science has any origins other than the Greek 'miracle' is solved in advance".

It is gratifying to note that recently, even European historians are coming round to accept the fact of Indian supe-

riority in Astronomy and Mathematics during several post-Christian centuries. We can not be termed as 'Chauvinist' if we quote the great British scientist-cum-historian, Prof. J. D. Bernal who writes in "Science and History" :

"There was also, and this is of the greatest importance for the whole world, a new development of science, particularly Mathematics and Astronomy, associated with the names of the two, Aryabhata and Varahamihira in the fifth century and with Brahmagupta in the seventh. . . . . A decisive new development was made there about this time : the perfection of a number system with place notation and a zero (Hindu numbers) . . . . . The Arabs also incorporated the work of a series of Indian mathematicians on the means of dealing with unknown quantities which we call algebra".

Aryabhata, the great Indian astronomer was born in 476 A.D. at Pataliputra (near Patna) and at the young age of 23 wrote his famous book on astronomy, 'Aryabhatiya'. He made the discovery that the earth rotates round its axis. His other scientific contributions include : discovery of trigonometric sine, accurate evaluation of π, perfection of decimal system of numbers, evaluation of A.P. and G.P. series and square and cube roots of numbers, accurate calculation of number of days in a solar year (upto seventh decimal point which is better than Ptolemy's figure), discovery of the causes of solar and lunar eclipses, prediction of duration and angular extent of eclipses etc.— a long list indeed. Aryabhata was the pioneer to introduce the concept of 'bijaganita' or algebra. He had been truly the first and the foremost mathematical genius, produced by the human race and a forerunner of Newton and other European mathematicians who were to be born more than thousand years later.

Varahamihira (born in 505 A.D.) made several observations on comets. He compiled Panchasiddhantika—five systems of astronomy, wherein apart from Indian systems,

Alexandrian and Roman astronomical systems were also discussed. In 'Brahatsamhita' Varahamihira mentions about the motions and conjunctions of celestial bodies. He referred to the properties of gems, which he believed to be nothing but metamorphosed stones.

After Aryabhata and Varahamihira, substantial advancements in Indian mathematics and astronomy were due to Brahmagupta of the seventh century. Born in 598 A.D. near Multan, Brahmagupta flourished in Ujjain where he wrote the astronomical treatises : Brahmasphutasiddhanta (628 A.D.) and Khandakhadyaka (664 A. D.). He was an opponent of Aryabhata's theory that the earth rotates round the sun. However, he substantially improved Aryabhata's method of astronomical calculations and computation of latitude and longitude. In his Brahmasphutasiddhanta, he extensively dealt with the properties of cyclic quadrilateral and trapezium and the relation between their sides, diagonals and area. He submitted the famous solution of indeterminate equations the second degree.

In the eighth century, Lalla amended Aryabhata's work (748 A.D.). Prthudaka and Mahavira, the Jain mathematician of Mysore (850 A.D.) were the two notable commentators of Brahmagupta's ideas during the ninth century. In his Ganitasarasamgraha, Mahavira was concerned with the properties of right-angled triangles, area and circumferance of ellipse, geometrical progression series and so on. He used his mathematical knowledge in various calculations on excavation and shadows. Manjula, the author of Laghumanasa (932 A.D.) and Sripati, the author of Siddhantsekhara (1039 A.D.) further extended the concepts of Indian astronomy and mathematics. Sridhara (1020 A.D.) in his treatise Ganitasara, gave a general rule for the solution of quadratic equations.

It is said that Bhaskaracharya (born 1114 A.D.) was the last astronomer-mathematician of repute produced by ancient

India. His Siddhantasiromani written in 1150 A.D. was divided into four parts : Lilavati (rule of arithmetic), Vijaganita (on algebra, root extraction), Grahaganitadhyaya (motions of the planets) and Goladhyaya (on calculations of the sphere). The entire treatise is a happy blend of poetic literature and prosaic scientific thoughts.

The first chapter, 'Lilavati' is addressed to "Beautiful and dear Lilavati, whose eyes are like a fawn's". Some of the mathematical questions are very interesting :

"Out of a swarm of bees, one fifth part settled on a blossom of Cadamba; and one third on a flower of Silindhri; three times the difference of those numbers flew to the bloom of a Cutaja. One bee, which remained, hovered and flew about in the air, allured at the same moment by the pleasing fragrance of a jasmin and pandanus. Tell me, charming woman the number of bees".

" In a certain lake swarming with ruddy geese and cranes, the tip of a bud of lotus was seen a span above the surface of the water. Forced by the wind, it gradually advanced, and was submerged at the distance of two cubits. Compute quickly, mathematician, the depth of the water".

Bhaskara advanced the concept of Bijaganita or algebra. He dealt on algorithm, zero and its use, unknown quantities, surds, the pulverizer or 'kuttaka', solution of quadratic equations and of certain equations of the third and the fourth degree.

H. T. Colebrooke in his book "Algebra, with arithmetic and mensuration from the Sanskrit of Brahamagupta and Bhaskara" (London, 1817) writes :

"The points in which the Hindu Algebra appears particularly distinguished from the Greek, are, besides a better and more comprehensive algorithm, first, the management of equations involving more than one unknown term, the second the resolution of equations of higher order, anticipating a

modern discovery in the solution of biquadratics, third, general methods for the solution of indeterminate problem of 1st and 2nd degrees, and lastly, application of algebra to astronomical investigation and geometrical demonstration."

The full solution of the Pellian equation $ax^2+e=y^2$ and its more general form $ax^2+bx+C=y^2$ was given by Bhaskara who developed the "cyclic" method. H. Hankel wrote in his 'Zur Geschichte der Mathematik' of this method: "It is beyond all praise; it is certainly the finest thing achieved in the theory of numbers before Lagrange."

The decimal notation and the use of zero have been unique Indian contributions to the world of science. The basic concept of decimal notation was known to the Indians during the time of Aryabhata.

W. E. Clark points out that the Indian numerals (0-9) were known to Severus Sebokt in a Syrian monastery on the upper Euphrates as early as 662 A.D. Again, the same Hindu decimal notation was used in the astrological treatise written by Chu-t'an Hsi-ta who flourished under the T'ang dynasty in the early 8th century A.D.

Zero represented by a dot appears in the famous Bakhshali manuscript. This manuscript, written sometime during the ninth century or earlier in old Sarada characters on seventy folios of birch-bark, was discovered in Kashmere in May, 1881 and presented to the Bodleian Library, Oxford by Dr. A.F.R. Hoernle in 1902.

Thus there are substantial evidences in favour of the Indian claim over the originality on the decimal system of numbers.

Advancement in Chemistry & Metallurgy

Based on Kanada's theory of atoms and molecules (500 B.C.), Indians refined their postulate on the constitution of matter. On the technological side, they made significant advances in metallurgy. Iron pillar of Delhi (built 4th Cen-

tury A.D.) a malleable rustless metal, welded to a tapering cylinder and exceeding six tons in weight, is a beautiful and standing tribute to the ancient Indian metallurgy. Iron pillars of Bhubaneswar (540 A. D.) and Konark (900 A. D.) have equally withstood the test of time. Solid copper bolt in Ramapura Ashoka Pillar (3rd Century B.C.), pure copper Buddha at Sultanganj made by casting (400 A.D.) and detailed descriptions on zinc metallurgy in Rasarnava (1200 A.D.) and Rasaratnasamuchaya are distinct evidences of lofty attainments in non-ferrous metallurgy in the ancient India.

Nagarjuna (700 A.D.) was an eminent authority on metallurgy and chemistry. His treatise, Rasaratnakara contains details on the apparatus for sublimation, distillation, extraction etc, as well as extensive uses of red sulphide of mercury ('makaradhvaja') and black sulphide of mercury ('Kajjali').

IV

Moslem invasions of India resulted in greater contact between the Indians and the foreigners. Harun and Mansur of the eighth century and Albiruni of the tenth century propagated Indian scientific thoughts to the Arab world which in turn influenced Western thoughts. However, this turned to be a one-sided advantage. While the Arabs and Persians benefited themselves with the newly acquired knowledge of Indian science, the invaders had very little desire or sense to patronise any further growth of education of science in India.

Inspite of the unfavourable circumstances, the Hindus did not give up scientific pursuits abruptly. South India resisted moslem invasion for a long period of time and thus retained the climate for scientific progress to some extent. In the 11th and 12th century, a medical school flourished at Tiruvadutarai. A compilation on botanical science was made in Sarngadharpadhati as late as the 13th century. Ganesa Daivadhya (born

in 1498 A.D.) gave reasonably accurate methods for calculating the mean positions of the sun, the moon and the planets in terms of their positions on the 19th March, 1520. The mathematicians of South India achieved some progress upto the sixteenth century. Nilakantha and his contemporary mathematicians (16th century A.D.) derived expressions for Sin $(\theta + \delta\theta)$ and infinite series for Sin , Cos θ and $\tan^{-1}\rho$. Munisvara of the seventeenth century improved on the astronomical systems of Bhaskara. Raja Jai Singh of Jaipur and his scholar Jagannath (18th century) tried to synthesise Hindu astronomy with the recent developments of the Samarkand school in Central Asia.

But those were scattered events and efforts, and for all practical purposes, the glory of Indian science which was at its zenith between the fifth and seventh century, had started to decline during the twelfth century after the death of Bhaskaracharyya.

Historians of Indian science should be concerned with two very vital questions : first, how science could flourish in ancient India and second, why there was a steep decadence of science in the mediaeval India.

In this article, we are interested only in the first question, a satisfactory answer to which should throw light on the second one as well.

The confluence of Aryan and Dravidian (or pre-Aryan) cultures was the starting point of Indian science. Crafts and techniques were not lacking in India when the Aryans entered this country. The logic and philosophy of science were however developed only during the Vedic period. Congenial climate and scenic grandeur naturally turned the Indians towards speculative thinking. Kapil, Kanad etc. were the products of this beautiful era when astronomy and geometry were developed in rudimentary form. There was the necessity of construction of ritual altars and of calculations

of astronomical events for different religious rituals. This need, coupled with the provision by the Vedic society for a special group of thinkers and educators, stimulated the early pursuit of science.

However, this rural civilisation could not possibly develop diverse arts and crafts; it was only after the age of the epics and particularly during the Maurya dynasty, that the transition from rural and agricultural, to urban and capitalistic economy took place, the role of money was established and merchants and craftsmen became supremely important in the society.

It has been aptly said that necessity is the mother of invention; the diversified needs of consumer goods in the affluent Indian society, where the producers and suppliers of the materials were abundant, naturally sustained steady growth of technological specialisation and of general scientific interest. The state-patronised capitalistic economy thrived for many centuries till it reached a perfection during the Gupta period (300-550 A.D.) which is rightly called the "golden age of India". During this period, trade and industry were organised in guilds and banking operations for raising necessary working capital were not uncommon. Fourth century sealings of a joint guild of bankers, traders and transport merchants with branches in towns and cities all over northern India, have been unearthed at Basarh, ancient Vaisali . For the purpose of transportation, knowledge of navigation and astronomy was necessary and the merchants patronised the study of these sciences. Some of them were able astronomers. They were also resourceful in the wielding of arms and could raise a militia at a short notice. There were direct commercial relations with the West by way of Persian gulf, Red Sea as well as land routes. Big Indian ships were engaged in high sea-way trades. Indian embassies found their places in the Roman empire during the reigns of Aurelian, Constantine etc.

Some Brahmins visited Alexandria in 470 A.D. and stayed in the house of consul Severus. Hindu temples were constructed in the upper Euphrates valley.

So, this was truly a period of cultural expansion of India. The Hindu society was undogmatic and open-minded in their contact with alien people. In the above-mentioned context, it is very easy to visualise why astronomical and other sciences were considered important in ancient India, what factors lay behind the emergence of scientific geniuses like Aryabhata and Varahamihira and how it was possible for them to be in fruitful touch with the contemporary scientific developments. Aryabhata mentioned that he had opportunities to study Greek and Roman astronomy in detail and could discriminate between the valid theories and the incorrect ones. Many Greek words e.g., Kentros (centre or 'Kendra') Orizos etc. were incorporated in Indian scientific vocabulary. Varahamihira wrote that although the foreign scholars are not Hindus, they are as worthy of respect as the ancient sages.

Fa-hien spent about 10 years in the Gupta empire (401-410 A.D.). His extensive report includes references to the great centres of learning,* liberal government and their patronage to education, instances of inter-caste marriages, abundance of hospitals, taxing system based on the richness of the locality, importance of the Vaisya (merchants) community, and above all effective law and order.

The following points distinctly emerge from the previous discussion : (1) the Hindus of ancient India were remarkably free from superstition and appreciated scientific logic and reason; (2) they were eager to communicate with the foreigners and to enlarge their respectable stock of knowledge by learning

* Many agrahara villages were centres of higher education, apart from capital cities and holy places like Varanasi, Nalanda etc. Logic, Philosophy and Astronomy were included in the curricula.

from whatever sources possible; (3) the ideal economic factors and the stable political atmosphere favoured an optimum growth of education and science in India.

The socio-economic conditions existing in India during the Gupta period bear close resemblance to those in Europe during the emergence of modern science (fifteenth century and onwards). Indians in the 4th and 5th century had started to feel the impact of scientific thinking in day-to-day life. Varahamihira wrote that since human lives are sustained by agricultural crops, the production of which depend on adequate rainfall, it is imperative that the laws which govern rainfall on the earth should be discovered. This remark bears adequate testimony to the logical growth of scientific thinking and practice that ancient India was experiencing.

In conclusion, a bold conjecture might be made : if India could retain political hegemony and stable economic conditions upto the tenth century, modern science might have emerged first in this country. The complex web of unfavourable social, economic and political factors in the mediaeval ages, which prevented such a golden possibility, is another fascinating topic, meriting a separate discussion.

AN EARLY SUNSET OF INDIAN SCIENCE —THE SOCIOPOLITICAL FACTORS

It would be presumptuous to write about the progress of science in India during the mediaeval period (between the twelfth and eighteenth century)—because, there was hardly any. Of course, the technical arts and crafts acquired during the preceding centuries were improved occasionally ; cotton, silk and carpet industries thrived ; after Babur's invasion, the Indians learnt the use of gunpowder and modelling of better cannons ; and the techniques of road — and bridge-making were improved —but none of these truly represented any advancement of science or scientific thinking. The purpose of this article is to analyse the socio-economic and political factors which led towards the steady decline and stagnation of Indian science during the Pathan and Moghul period and prevented any intellectual resurgence till the British rule started in this country. Brief references to European, Chinese and Japanese social conditions during the mediaeval period would be made to illustrate the viewpoints.

During the Hindu period, at least upto the 6th century A.D., India enjoyed remarkable prosperity and peace. Inspite of occasional provincial conflicts, animosity between neighbouring kingdoms was often resolved in a peaceful manner. The Hindu monarchs were tolerant in religious matters. Progress of science and education was largely due to the patronage and critical appreciation of kings like Vikramaditya, and also due to favourable social factors.

It was however a different story after the 6th century. Like Europe, the Indian subcontinent experienced the terrible Hunnish invasions. After the emergence of the forces of Islam, the Arabs started their marine expeditions to the west

coast of India ; Sind collapsed in the 8th century. The Hindu navy was often humiliated and the Arabs forced as many Hindus as they could to embrace Islam. The Hindu rulers in India were lacking in political wisdom. Instead of uniting against the invaders, they were often at loggerheads with each other. A powerful religious head could have perhaps exhorted the Hindu rulers to unite against the foreign invaders — just as the Vatican united the Christians for the crusade wars. But the liberal-minded Hindus never had any common religious figurehead and thus their society always lacked political cohesion.

The chaotic social conditions could hardly encourage any scientist or intellectual. The professions of craftsmen and merchants were beset with many difficulties — and were chronically insecure. But the worst feature happened to be the intellectual bankruptcy of the Hindus. As an outcome of affluence in the 4th and 5th century and international fame enjoyed by the Indian science and culture, vainglory had set in the hearts of the Indians.

Albiruni, the famous foreign scholar of the 11th century travelled throughout India mainly to study the Indian science and philosophy, of which he was a great admirer. His records reveal that the contemporary Hindus were not only disunited but strangely overcome with foolish vanity and parochialism which contrasted the thirst for knowledge and humility that had marked the Indians of the age of Varahamihira. "The Hindus", he wrote, "believe that there is no country but theirs, no nation like theirs, no king like theirs, *no science like theirs* (italics are mine). They are haughty, foolishly vain, self-conceited and stolid.............. If they travelled and mixed with other nations, they would soon change their mind, for their ancestors were not as narrow-minded as the present generation is". Thinking naively that the Hindu science and culture had already attained the unsur-

passable height, the Indians neglected the noble task of acquisition of further knowledge.

There is no reason to believe that even in the age of Aryabhata and Varahamihira, the reactionary forces were totally absent in the Hindu society. The caste system was becoming gradually rigid. Later, the duty of philosophical studies (which included speculative aspects of science) was assigned exclusively to the Brahmins, whereas, the practical arts were assigned to the non-Brahmins. This prevented co-ordination between science and crafts. Moreover, different languages evolved out of Sanskrit, and a common technician having little opportunity or capability to study the scientific texts in Sanskrit, became cut off from the mainstream of Indian scientific thoughts evolved in the previous centuries. Those who studied the Sanskrit texts had little fascination for experimental science and scarcely felt the necessity to translate the Sanskrit texts into the newly evolved languages and thereby to popularise science among the masses. This divorce of theoretical from practical studies of science had been so complete by the 12th century that no Indian, whether Brahmin or non-Brahmin could possibly appreciate the inviolable relationship between a scientific truth and its experimental verification.

The invasions and daring piracy of the Arabs created great turmoil not only in the political life but also in the social life of the Hindus. While political unision was a far cry, the advocates of the reactionary forces persuaded the rulers of the country to stop emigration of scholars or merchants—since they would be either maltreated or converted to alien ways of life, by force or persuasion. (In the 15th century, the Chinese emperors took a similar decision in the face of Japanese and European hostilities in the sea). Thus, the most progressive nation in the world turned itself towards conservatism and painful physical and cultural seclusion. The

people who had carried message of wisdom all over Asia, now declared that eating with foreigners or even with fellow citizens of different caste was punishable and an act of sea-voyage needed atonement !

This curious mixture of vainglory, dogmatism and lack of political wisdom in the Indian people had already predestined an early eclipse of their science.

The situation was hardly improved by the Moslem invasions and here again, the unbiased historian Albiruni describes the contemporary situation :

"Mahmud utterly ruined the prosperity of the country, and performed there wonderful exploits, by which the Hindus became like atoms of dust scattered in all directions, and like a tale of old in the mouth of the people. Their scattered remains cherish of course, the most inveterate aversion towards all Muslims. This is the reason too why Hindu sciences have retired far away from those parts of the country conquered by us, and have fled to places where our hands cannot yet reach, the Kashmir, Benaras (Varanasi) and other places. And there the antagonism between them and all foreigners receives, more and more nourishment both from political and religious sources".

The barbarity of the early moslem invaders in India shocked even the Arab intellectuals. For example, Shaikh Bu Ali Sina, a respected physician and biologist refused to come to India with Mahmud, whose plunder and loot, he felt, was destroying Indian science. European history would have perhaps followed a similar dreadful course, if there were no united Christian front in the religious wars and if the Moslem invasions of the Iberian peninsula were not finally stopped at the battle of Tours in 732 A.D. In India, the Moslems faced an opponent which was militarily weak and thus vanquishable, but culturally strong and hence not easily proselytisable. This desperate situation generated only hatred ; the rulers

and the ruled refused to learn from each other on educational and scientific matters.

The Pathan rules did not completely destroy Indian trade and industry; Bengal and Gujrat continued to remain as important centres for manufacture of silk and cotton goods. Repeated invasions (like that of Timurlang in the 14th century) however prevented any recovery of Indian economic prosperity. The invaders systematically destroyed not only temples but also centres of learning containing scientific books. There is little wonder that when Babur conquered part of India, he remarked that there was no educational institution of repute in the country.

The Indian as well as the Asian history of the mediaeval ages (10th to 16th century) is characterised by systematic wars of invasion and destruction of assiduously built schools of learning. While the Moslems learnt science from the Hindus, cultivated and then propagated the same in the Christian world particularly in the Spanish cities of Cordoba, Granada, Seville and Toledo, they had nevertheless annihilated Hindu academic institutions in India. Similarly, the famous Ulugh-beg (grand-son of Timurlang), who erected a fine astronomical observatory at Samarkand (1420 A.D.) and whose astronomical tables, Zij Ulughbeg (published in 1437 A.D.) was later translated and used by the British scholars of the Oxford University, had mercilessly destroyed the city of Baghdad and its scientific institutions!

For several centuries after Bhaskaracharyya, there persisted an intellectual vacuum in India, in which scientific pursuit was well-nigh impossible. In 1470 A.D., Saif-ud-din Salman, a young astronomer from Kandahar working then at the celebrated observatory of Ulughbeg at Samarkand, wrote an anguished letter to his father. The poignancy in this letter reflects the contemporary situation, frustrating all scientific attainment:

"Admonish me not, my beloved father for forsaking you thus in your old age and sojourning here at Samarkand. It's not that I covet the musk-melons and the grapes and the pomegranates of Samarkand; it's not the shade of the orchards on the banks of Zar-Afshan that keeps me here. I love my native Kandahar and its tree-lined avenues even more and I pine to return.

"But, forgive me my exalted father, for my passion for knowledge. In Kandahar there are no scholars, no libraries, no quadrants, no astrolabes. My star-gazing excites nothing but ridicule and scorn. My countrymen care more for the glitter of the sword than for the quill of the scholar. In my town, I am a sad, a pathetic misfit.

'It is true, my respected father, so far from home men do not rise from their seats to pay me homage when I ride into the bazar. But someday soon all Samarkand will rise in respect when your son will emulate Biruni and Tusi in learning and you too will feel proud*".

The last scientific work in the pre-British India has been Raja Jai Singh's compilation of astronomical tables, "Zij Muhammad Shahi" (1728 A.D.). In the preface to the above compilation the stagnancy of Indian science for several centuries has been regretted and lamented upon :

" The (astronomical) revision was a mighty task, which during a long period of time none of the powerful Rajas had prosecuted; nor among the tribes of Islam, since the time of martyr prince, whose sins are forgiven, Mirza Ulugh-beg to the present, *which comprehends a period of more than three hundred years*, had any one of the kings possessed of power and dignity turned his attention to this object".

* This beautiful letter has been quoted by Prof. Abdus Salam in his article, "The isolation of the scientist in developing countries", published in 'Minerva' Vol. 4, No. 4, pp. 461-465, 1966.

II

The Moghuls had a firm grip on Indian politics for more than two centuries (early sixteenth to early eighteenth). Yet they did very little to improve educational standards in the country. Education continued to be classical in the main and divorced from the scientific spirit which had recently emerged in the Moslem countries and Europe. No doubt, the Moghuls appreciated and patronised painting, music and architecture etc., and exceptional people like Akbar and Dara Shikoh went so far as to be interested in the world religions and comparative theology; but none of them took any advantage of their contact with the Moslem world outside India which was producing scientists of repute.

Patriotic feelings have prompted Indian historians to call Akbar as 'the great'. But, time has come when we should dispassionately evaluate his career and policies with particular reference to education and science. Akbar was certainly the best of the Moghul rulers and his efficient administration and liberal outlook towards religion deserve praise. But as a monarch, he was never free of egoism, and believed that, "a monarch should ever be intent on conquest, otherwise his enemies rise in arms against him" ('Happy Sayings', Ain-i-Akbari by Abu-l Fazl. English translation vol iii p. 399). In martial spirit, he was not radically different from Aurangzeb. He was kind to the Hindus, but not to the independent-minded Hindu rulers like Rana Pratap. Whether he sincerely desired to synthesise Hindu and Moslem culture is debatable*. The more important criticisms are that : he never planned political unification of the country, did precious little to check the naval supremacy of the Portugese (when his

* In his newly proclaimed religion, Din Ilahi, he assumed the powers of religious authorities with the hope of becoming a monarch cum pope and prophet. He once said, "the very sight of Kings has been held to be a part of divine worship". Father Pinheiro writing from Lahore on Sept. 3, 1595 mentioned that in the city, the royal sect had many adherents, but all for the sake of the money paid to them.

female relatives wanted to go to Mecca for pilgrimage in 1575, Akbar had to take assurance for their safety from the Portugese) and devoted little attention to the improvement of educational standards and science in India. The last criticism needs some amplification.

Akbar was well aware of Portugese superiority in naval architecture, artillery, astronomy, medicine etc.—but he was more interested in theology! At about 1578, Haji Habibullah was sent to Goa with instructions from Akbar to bring back European articles and commodities. Haji brought back many interesting articles, but special admiration was bestowed on an organ 'played by a European sitting inside'. Akbar sent an invitation letter to the Portugese office at Goa to send "two of your learned men, who should bring the books of the law, and above all the Gospels".

Abu-l Fazl writes in Ain-i-Akbari (book ii, Ain 25) about the educational standard during Akbar's regime :

"The boys should be required to read books on morals, arithmetic, the notation peculiar to arithmetic, agriculture, mensuration, geometry, astronomy, physiognomy, household matters, the rules of the government, medicine, logic, the theological (ilahi), the mathematical and physical (riyazi and tabi'i) sciences, as well as history, all of which may be gradually acquired".

Vincent Smith boldly and perhaps rightly asserts that no school in India during the Moghul period tried such an ambitious program. There was no Indian scientist of repute at that period. None of the famous foreign Moslem scholars (like the mathematicians and astronomers of Ulugh-beg madrasah of Samarkand, of whom the Moghul rulers were aware) were invited to teach in Indian schools. Akbar himself was not ashamed of his inability to read and write, and his sayings include the maxim :

"The prophets were all illiterate. Believers should

therefore retain one of their sons in that condition". ('Happy Sayings', Ain, Vol. iii. p. 385).

In this respect, Aurangzeb deserves some praise; at least, he was regretful, unlike Akbar, about the inadequacy of his education. Bernier describes how Aurangzeb rebuked his one time teacher Molla Shah for not having taught him anything about European history and geography or Western science. Auranzeb felt that over-emphasis on classical education based on Arabic was unnecessary and that the degradation of the Asian countries was largely due to imperfect and incomplete education acquired by the princes. Inspite of these laudable sentiments, Aurangzeb could not do much to improve educational standards in the country due to the political storms which were created by his own religious fanaticism.

We need not overlook what might be called the brighter sides of the Moghul reign. Raja Jai Singh of Jaipur (1686-1743 A.D.) tried with the help of his astronomer, Jagannath to synthesize Hindu and Samarkand systems of astronomy. He built observatories at Delhi, Jaipur, Ujjain, Varanasi and Mathura. His astronomical compilation has been earlier referred to. However, when he died in 1743, fourteen years before the battle of Plassey, "his wives, concubines and science expired with him on the funeral pyre". Large scale productions of shawl continued at Kashmir and also of cotton cloths at Gujrat, carpets at Agra and delicate fabrics at Sunargaon in Bengal. The government earned huge revenue from export of these commodities. But very little effort was made to alleviate the poverty of the industrial workers, to prevent the economic exploitation on them, or to help them improve their technical skill. Ali Mardan Khan's remarkable feats as an engineer (his work on the Ravi canal in 1639 and on the Shalimar Gardens) and the architectural fancy at Tajmahal are usually cited as the glories of Shah Jahan's reign, but it must be clearly understood that "this glory was purchased

at the cost of large suffering to the peasants and aritisans of the country", as the famous traveller Bernier put it.

III

The reasons for lack of dynamism in the mediaeval India were deep-rooted. One of the basic reasons was the adverse balance of trade between the West and the East, including India. Right from the beginning of the Christian era till the industrial revolution in Europe (18th century), the West was dependent on Asia and particularly India for many consumer commodities. The monopoly of the Arabs in trade and navigation made the Europeans desperate, since to them trade was as important as agriculture. The entire West made concerted efforts to discover alternate routes to India. These restless efforts had to be (and indeed were) backed up by positive encouragement to the pioneers of science and technology who flourished in different European countries.

On the other hand, the Chinese and Indian economy were agrarian and self-sufficient *. There was very little necessity for international trade. Even the domestic consumption of commodity articles manufactured in India was largely restricted to the emperors and the wealthy men of the country, and thus the domestic trade was very small in volume.

Bernier reported that in Delhi there was no middle class

* The Chinese who invented paper, gunpowder, printing and the mariner's compass were intelligent but thought like the Indians, that their civilisation was perfect and economy complete. Ch'ien Lung, one of the emperors in the 18th century told the Western ambassadors that it was praiseworthy of them to try to partake of the benefits of Chinese civilisation, but the Chinese need not accept the Western civilisation. He said "China possesses all things in abundance, and we do not want your products". As a contrast, the Japanese people, never suffering from any superiority complex of the above kind, were conscious of the need of international commerce. They were also the first in Asia to realise that commerce could not be improved without Western science and technology.

people in between the extremely wealthy and the miserably poor. This is understandable since most of the national wealth was concentrated in the bullions and treasures hoarded by the Moghul emperors, who had proverbial lust for gold and silver. When Akbar died in 1605, he left behind 40 millions of pound sterling (equivalent in purchasing power to about 10-20 times as much money at the present time) ; and yet a very negligible fraction of the revenue was spent on education and agriculture, the industries in Bengal and Gujrat were starving for lack of capital and famines were rampant and widespread. The military conquests, arson, loot and plunder of the Moghul and Maratha armies successfully exterminated whatever was left of Indian industry and technology (Shivaji's plunder of the industrial centre of Surat alone exceeded ten million rupees).

Land-holders, aristocrats, property-owners and merchants have often played significant roles in promoting and patronising science and technology. Studies on Western history as well as Indian history during the Gupta period reveal this truth. During the Moghul dynasty however, one of the most significant and notorious rules was that the land and other properties of a person could not be inherited by his descendants and after the death of the person, the property would be usurped by the emperor who was the only legal owner in the country. This monstrous lack of social security killed all initiative and even the wealthiest did not think of promoting education or industrial ventures in the society — since, he thought that these acts would hardly benefit his descendants after his death. The monarchical autocracy was in its full play. The element of fatalism in Indian thought must have originated only in the mediaeval ages. At a time when democracy was slowly emerging in the western countries and the merchants, craftsmen and scholars were bringing social and industrial revolution in Europe, Indian people in general

and the 'remarkably efficient' technicians in particular were at the mercy of ruthless autocrats and exploiters who never understood the spirit of scientific and technological progress.

The famous historian, Jadunath Sarkar remarked that "Aurangzeb rather quickened the destructive forces already in operation in the land ; he never realised that there cannot be a great empire without a great people". But, is not this remark applicable to some extent to most of the rulers of mediaeval India not excluding Akbar and Shivaji ? Is it not true that the concept of Indian nationhood never crystallised for thousand years after the 8th century A.D. ?

The vastness of the Indian sub-continent was perhaps a factor against lasting national unity without which political stability and optimum growth of scientific education and research could not be expected. India and China were preoccupied with land ; their neglect of naval forces (unlike as in Japan or England) made these two powers easy prey to vigorous maritime states. But the additional and more important factor in the case of India was that the country happened to be the scene of bloody rivalries of hostile cultures *. Due to the internecine wars, India had become so weak, not only culturally but also militarily, that the Italian traveller Manucci, who visited India during Aurangzeb's reign, affirmed that "30,000 good European soldiers could easily sweep away the authority of the Mughal and occupy the whole of his empire". This remark was prophetically proved within fifty years after Aurangzeb's death (1707).

A study of the Japanese socio-political condition which heralded the birth of modern science in that country is extre-

* Apart from the perpetual conflict between the Moslems and the Hindus and Sikhs, tension existed between the two Moslem communities: Shia and Sunni. In 1700, Aurangzeb vanquished the Shia empire of Bijapur. Along with the economically prosperous capital of Bijapur, half its population was extinguished; the intellectual and the industrial life of this southern state was thus effectively annihilated.

The evil of communalism still plagues this sub-continent.

mely rewarding, particularly because it offers a striking contrast to the Indian scene. Like England, Japan has been geographically small and well-demarcated by the sea from the neighbouring continent. Japan did suffer from civil wars but at the threat of European expansionism, quickly regained political cohesion. Never suffering from superiority complex, the Japanese people were always eager to learn, and being dependent upon exports and maritime trade, quickly appreciated the importance of commerce based on science and technology. Sakuma, one of the scholars in the early 19th century wrote :

"How is it that Western countries have been able by devotion to learning to increase their national strength to such a point that even the country of Confucius has fallen victim to their assault ? It is because foreign learning is rational and Chinese learning is not".

Fukuzawa, the pioneer of modern and pragmatic education in Japan preached the gospel of science and modernism in his widely read book, 'Gakumon no Susume' or 'Encouragement of Learning'. To crown the efforts of the Japanese scholars and scientists, Emperor Meiji democratised the country, boosted national trade and industry and with the help of foreign scholars, accelerated the pace of cultivation of science in Japan.

A study on the history of science in different countries clearly brings out one great moral : if a nation wishes to remain economically prosperous and foremost in the contemporary world, it must make concerted efforts for promotion of science and technological advancement in the country. After the golden age of the Gupta period, Indians forgot this lesson, at the cost of untold misery and degradation. Raja Rammohun Roy, the father of modern India regained this historical perspective and initiated another new chapter in Indian science.

REVIVAL OF SCIENTIFIC STUDIES IN INDIA

During the Muslim rule, there was hardly any progress of science or scientific attitude towards life in India. The tradition of Hindu Science was extinct due to alien rule and oppression, rigid caste system and the barrier between the classical language (Sanskrit) and the regional languages. By the fifteenth century, the Muslim world also collapsed economically and culturally. There was hardly any intellectual drive from the Moghul rulers in India. "India had become a battleground between waves of Islamic invaders and a Hinduism frozen in a caste structure that provided stability at the expense of any possibility of advance".

On the other hand, the West was emerging from the shackles of mediaeval scholasticism. The European renaissance in the middle ages strikingly resembled the glory of Hindu India during the fifth and sixth century A.D. In both the cases, political hegemony, importance of merchant and middle class acknowledged by the rulers, widespread contact with the outer world and the intellectual freedom of intelligentsia from the rule of religious dogma accounted for the steady progress of scientific thought and attainments.

By the middle of the 18th century when the Britishers were changing their garb of traders to that of rulers in India, they represented a superior nation, the nation of Bacon and Newton. Raja Rammohun Roy was the first Indian who appreciated this historic perspective. Steeped in the knowledge of ancient literature in Arabic, Persian and Sanskrit, he keenly felt the impotence of classical studies, unsupplemented by modern scientific knowledge discovered in the West. According to him, there was no chance of India's progress whether in political or intellectual field unless she borrowed modern ideas from Britain. Rammohun wrote very candidly :

"The greater part of Hindustan having been for several centuries subject to Muhammadan rule, the civil and religious rights of its original inhabitants were constantly trampled upon.........Divine providence at last in its abundant mercy, stirred up the English nation to break the yoke of those tyrants". Dwarkanath Tagore, grandfather of Rabindranath Tagore wrote in a letter to the "Englishman" dated 6th December 1838 :

"The Mahomedans introduced in this country all the vices of an ignorant, intolerant and licentious soldiery. The utter destruction of learning and science was an invariable part of their system".

During the 18th century, educational facilities were available in the country exclusively in the *Tol's*, *Chatuspathi's* and *Madrasa's* which imparted Hindu and Muslim religious teachings in Sanskrit, Arabic and Persian. William Adam's report reflects on the state of indigenous educational institutions in the early 19th century. The emphasis in the Hindu schools was mostly on theology, grammar and logic. Some instruction was imparted on astronomy with reference to construction of almanacs and calculation of eclipses. At the Madrasas in Murshidabad, the curriculum included theology, grammar as well as Euclid's geometry and astronomy. The quality of teaching was very poor and many teachers were "as ignorant as owls". Textbooks and manuscripts were rare and hence most of the teaching had to be from memory. Scientific thinking was at its lowest ebb.

Although the standard of education and science in India was very low, the intellectual and industrial capabilities of Indians were remarkable and this did not escape the notice of Western observers. Reginald Heber was the Lord Bishop of Calcutta in the early 19th century. He travelled widely in the sub-continent. He remarked about the contemporary Indians :

"They are men of high and gallant courage, courteous, intelligent and most eager after knowledge and improvement with a remarkable aptitude for the abstract sciences, geometry, astronomy etc. . . . . To say that the Hindus or Mussalmans are deficient in any essential feature of a civilised people, is an assertion which I can scarcely suppose to be made by any who have lived with them. . . . . Nor is it true that in the mechanical arts they are inferior to the general run of European nations. Their goldsmiths and weavers produce as beautiful fabrics as our own . . . . The ships built by native artists at Bombay are notoriously as good as any which sail from London or Liverpool."

The above extensive quotation from Bishop Heber's remark proves that an average Indian was capable of and receptive to the acquisition of new knowledge and particularly scientific knowledge which the West had to offer.

Seventeen years after the battle of Plassey (1757), was born the greatest citizen and the father of modern India, Raja Rammohun (1774) who later became the crusadeer for the Western and scientific education in India. The same year, Warren Hastings was appointed the Governor General; apart from his intense politieal activities, he took keen interest in the educational facilities in the country. Largely through his efforts, Calcutta Madrasa was founded in 1781 and Banaras Sanskrit College in 1791. These institutions were the first meeting grounds of the oriental and occidental scholars.

However, the advent of scientific efforts in India according to newer occidental methods probably dates with the foundation of the Asiatic Society in Calcutta, on January 15, 1784 by Sir William Jones, Judge of the Supreme Court. The orientalists like Hastings and Jones were eager to unravel the mysteries of the Indian subcontinent—its geography, history and culture and thus unknowingly initiated the trend of modern research in this country. William Jones described the excite-

ment he was having (as regards prospect of scientific research in India) while he was approaching India over the Arabian sea: "It gave me inexpressible pleasure to find myself in the midst of so noble an amphitheatre almost encircled by vast regions of Asia, *which has ever been esteemed the nurse of sciences*, the inventress of delightful and useful arts, fertile in the production of human genius, abounding in natural wonders . . . . I could not help remarking how important and extensive a field was yet unexplored, and how many solid advantages unimproved."[1]

Sir William Jones was the pioneer to study the Indian plants and classify these according to the modern botanical system. In recognition to his efforts, William Roxburgh named the beautiful Asoka tree for him : Jonesia Asoka.

The Asiatic Society, true to the vision of its founder, continued to be the Mecca for oriental scholars and natural scientists. Some of the early publication in the Society proceedings may be cited :

"On the cure of elephantiasis, and other disorders of the blood "—translated from original Sanskrit (Jones, 1785).

" Musical modes of the Hindus" (Jones, 1789).

"The design of a treatise on the plants of India" (Jones, 1789).

"On the antiquity of the Indian Zodiac" (Jones, 1789).

" Musical Scales of the Hindus" (Paterson, 1807).

"Temperature and Saltiness of Hugli" (Prinsep, 1832).

"Bhaskara's knowledge of Calculas" (Sastri, 1858).

Since the middle of the nineteenth century, the Society published many original articles on Zoology, Botany, Anthropometry, Physics, Meteorology, Chemistry, Geology, and Medical sciences, and thus played a crucial role in regeneration of science in India. Sir J. C. Bose, P. C. Ray, Ashutosh Mukherji and many other Indian scholars used the forum of the Asiatic Society to communicate to the general public, the

results of their scientific investigations. The Society had large collections of ancient coins and geological and archaeological specimens; through its efforts, Indian Museum of Calcutta was founded in 1856.

The primary purpose of the early British scholars was to study India, but one off-shoot of their efforts was that the collaborating Indians started to appreciate the methodology of Western scientific approach. It became clear to the enlightened Indians and the foreign scholars, that improvement of educational facilities in India was an absolute necessity.

William Carey, a cobbler in Northamptonshire, embarked upon an evangelical mission and came to Calcutta in 1793. With the help of William Ward & Joshua Marshman, he started the famous Serampore Mission. He did splendid work in promoting education and improving vernaculars and vernacular presses in different parts of India. The Fort William College was established in 1800 for the study and training of British Civilians. William Carey joined this college as a teacher of Bengali and Sanskrit in 1801. He composed a book on Bengali dictionary, with the help of Mrityunjoy Vidyalankar. The vernacular presses like 'Digdarshan' (April 1818) became the ideal vehicle for dissemination of scientific thoughts and education amongst the masses.

In 1811, Lord Minto remarked that there was a progressive decay of ancient education and science in Bengal and hence new educational facilities must be introduced. Largely due to his efforts, a clause was included in the East India Company's Charter in 1813 that: "A sum of not less than one lac of rupees in each year shall be set apart and applied to the revival and improvement of literature and the encouragement of the learned natives of India and for the introduction and *promotion of a knowledge of the sciences* among the inhabitants of the British territories in India".

William Carey submitted a plan in June 1814, for " ins-

tructing the natives of India in European Science." According to him, the Fort William College should have separate departments in Mathematics, Mechanical Philosophy and Natural Philosophy. Almost simultaneously, J. H. Harrington of the Sadar Diwani Adalat suggested that the Hindu College of Banaras and the Madrasa at Calcutta should include curricula in science. Leading Hindus of Calcutta founded Hindu College in 1817 with the object that their children may get adequate foundation in European arts and science (Geography, Astronomy and Mathematics).

It was largely due to the inspiration of Raja Rammohun and his followers as well as David Hare and William Carey that Western liberal education was accepted in India. The Hindu College ushered in an era of intellectual renaissance first in Bengal and then in India. Old dogmatic ideas were challenged; blind superstition and ignorance were replaced by a rational and scientific attitude towards life, without which modern science could not flourish in Indian soil.

Enthusiasm for Western education was great among the Calcutta citizens—and this is amply demonstrated in the news given in the contemporary English and vernacular periodicals. There were two dozens of British styled schools in Calcutta before 1835, when Macaulay pleaded for further dissemination of Western education in India. Rev. Duff of the Scottish Churches later wrote about that time: "The excitement for Western education continued unabated. They pursued us along the streets."

Some of the British orientalists favoured education in the classical Indian style. However, Raja Rammohun Roy clearly perceived the futility of such retrogression. The cogent exposition of his liberal ideas pleading for modern science in the academic curriculum remains as the turning point in the history of renaissance of Indian Science. His letter to Lord Amherst written on December 11, 1823 protesting against the

Governmental moves to establish Sanskrit schools deserves extensive quotation :

" This seminary (similar in character to those which existed in Europe before the time of Lord Bacon) can only be expected to lead the minds of the youth with grammatical niceties and metaphysical distinctions of little or no practical use to the possessors or society. The pupils will there acquire what was known two thousand years ago with the addition of vain and empty subtleties since then produced by speculative men, such as is already commonly taught in all parts of India. . . ."

"In order to enable your Lordship to appreciate the utility of encouraging such imaginary learning as above characterised, I beg your Lordship will be pleased to compare the state of science and literature in Europe before the time of Lord Bacon with the progress of knowledge made since he wrote.

"If it had been intended to keep the British nation in ignorance of real knowledge, the Baconian philosophy would not have been allowed to displace the system of the schoolmen which was the best calculated to perpetuate ignorance. In the same manner, the Sanskrit system of education would be the best calculated to keep this country in darkness, if such had been the policy of the British legislature. But as the improvement of the native population is the object of the Government, it will consequently promote a more liberal and enlightened system of instruction, embracing Mathematics, Natural Philosophy, Chemistry, Anatomy, with other useful sciences, which may be accomplished with the sums proposed by employing a few gentlemen of talent and learning educated in Europe and providing a college furnished with necessary books, instruments and other apparatus".

As a result of Rammohun's advocacy, Bentham and John Mill's utilitarian approach gradually pervaded the educational

policy of the British rulers. Rammohun's forceful pleas for science in India augmented the like efforts of his predecessors and served as a beacon-light for the future aspiration of Indians and Asians in the realm of science.*

European and Indian scholars established Calcutta School Book Society on the 8th of July, 1817. The object of the Society was "preparation, publication and cheap or gratuitous supply of works useful in schools and seminaries of learning." With Calcutta as the centre, this kind of activity spread throughout the country and within one decade, Book Societies sprang up at Dacca, Murshidabad, Bombay and Madras. E.S. Montagu one of the early editors of the Society acknowledged : "Our most useful works are in Bengalee." The first few books published in Bengali by the Society were : 'Mathematics' by William May (1817) ; Feguson's 'An easy introduction to Astronomy for young persons' translated by William Yeats (1833) etc. Works on geography by John Clark Marshman and William Hopkins Pears were published from Serampore. Felix Carey, son of William Carey compiled a scientific encyclopaedia in Bengali. His knowledge in Chemistry, Medicine and Astronomy was profound.

John Mack, a missionary teacher of Serampore College arrived in India in 1821. William Carey remarked of him : "He was especially attached to the Sciences of Chemistry, which he had cultivated with success under the most eminent professors in London. . . . . Soon after his arrival in India, he gave a series of chemical lectures in Calcutta, the first ever delivered in the city; and at a later period, prepared an

* Half a century later, Fukuzawa, the pioneer of scientific education in Japan was arguing in the same vein in favour of utilitarian teaching in science and against old classical teaching: " A man who can recite the chronicles but does not know the price of food, a man who has penetrated deeply into the classics and history but cannot carry out a simple business transaction—such people as these are nothing but rice-consuming dictionaries . . . How many Chinese scholars have been good at managing their domestic affairs? What is really wanted is learning that is close to the needs of a man's daily life."

elementary treatise on this science, and translated it into the Bengalee language for the use of native pupils." John Mack was truly a pioneer as regards teaching of Chemistry, Mechanics and Astronomy in India. "There were few branches of natural science in which he was not at home, and in which he did not succeed in keeping himself upto the level of modern discoveries."

During the twenties and thirties of the nineteenth century, most of the scientific education was imparted in the Hindu College and Medical College. British India Society of London sent scientific equipments related to Astronomy, Optics, Chemistry and Mechanics. These equipments reached Hindu College in April, 1823 and were ably utilised by Profs. Tytler (Mathematics), Ross (Chemistry) etc. Indian students like Radhanath Sikdar (of Everest fame) and Krishnamohan Banerji received inspiration from the early teachings in the Hindu College.

In 1827, medical classes were opened in the Calcutta Madrasa to teach the *Unani* system and in the Sanskrit College to teach the Ayurvedic system. A report of Sanskrit College in 1828 said that the teaching of Medicine and Anatomy was progressing well and that "the students had learnt to handle human body without apparent repugnance and had assisted in the dissection of other animals". The descendants of Charaka and Susruta had been abhorring dissection of dead human bodies for more than one millennium and it was the credit of Dr. John Tytler that he could persuade them to study Anatomy and Surgery. A committee appointed by Lord Bentinck in 1833 recommended the establishment of a new medical institution where "the various branches of medical service cultivated in Europe should be taught and as near as possible on the approved European system." This recommendation was accepted. The Government suspended medical classes in the Sanskrit College and Calcutta Madrasa; a

new medical college on the Western style was founded in 1835. This was held as a triumph of the anglicists over the orientalists.

Since the historic letter of Rammohun to Lord Amherst in 1823, a great controversy was raging throughout the length and breadth of the country; this was pertaining to what should be the contents and medium of instruction in Government sponsored schools. Orientalists like Hastings, Jones, Prinsep etc. had been in favour of propagating education in Sanskrit, Arabic and Persian. They were however not against Western science which they believed could be incorporated in classical Hindu and Muslim schools. The arithmetic and algebra of the Hindus, they argued, were grounded on the same principles as those of Europe; the elements of mathematical science taught in the Madrasa were those of Euclid. However, the anglicists like Rammohun and (later) Macaulay strongly felt that the oriental science was far less developed than the European science; utilitarian education was more important than the stereotyped classical education and English was the best medium for dissemination of scientific knowledge. A third group represented by William Carey, and later Mountstuart Elphinstone of Bombay Presidency advocated the use of vernacular languages.

James Prinsep and other orientalists submitted in the thirties that translation of scientific works into Sanskrit and Persian was well in progress and argued against English: "A foreign tongue is forgotten as soon as learnt unless constantly kept in memory by practice". However, it could be argued that Sanskrit and Arabic were no less foreign than English to the inhabitants of Indian villages. William Adam surveyed the educational facilities in Bengal villages. He criticised both the orientalists and anglicists by saying that their approach would lead to confine higher education

amongst upper and middle classes. He suggested that English should hardly be the medium for transmission of knowledge of any kind to Indian villagers : "It is difficult to believe that it should have been proposed to communicate to this mass of human beings through the medium of a foreign tongue all the knowledge that is necessary for their higher civilisation, their intellectual improvement, their moral guidance and their physical comfort." Adam's point of view was subsequently corroborated by Mountstuart Elphinstone who encouraged science teaching in vernaculars in Bombay Presidency and by Dr. F. J. Mouat who reported success of science teaching in Urdu in the Delhi College.

Debates and confusion continued till 1835, when Macaulay, the great anglicist submitted his historic note to the Governor-General. The note was full of rhetoric and arguments and brought forth Rammohun's point of view in candid fashion (except that, Rammohun's erudition and reverence for classical languages of Arabic and Sanskrit was replaced by Macaulay's ignorance and contempt). Macaulay's note dated 2nd February 1835 deserves extensive quotation :

"All the parties seem to be agreed on one point, that the dialects spoken among the natives of this part of India contain neither literary nor scientific information, and are moreover so poor and rude that until they are enriched from some other quarter it will not be easy to translate any valuable work into them. It seems to be admitted on all sides that the intellectual improvement of those classes of the people who have the means of pursuing higher studies can at present be effected only by means of some language not vernacular amongst them. What then shall that language be ? One half of the Committee maintain that it should be English. The other half strongly recommend Arabic and Sanskrit. . . . I am quite ready to take the oriental learning at the valuation of the orientalists themselves. I have never found one

among them who could deny that a single shelf of a good European library was worth the whole native literature of India and Arabia. . . . But when we pass from works of imagination to works in which facts are recorded and general principles investigated the superiority of the Europeans becomes absolutely immeasurable. . . .

"In India English is the language spoken by the ruling class. It is spoken by the higher class of natives at the seats of Government. It is likely to become the language of commerce throughout the seas of East. . . . ."

"The question now before us is simply whether, when it is in our power to teach this language, we shall teach languages in which by universal confession there are no books on any subject which deserve to be compared to our own; whether, when we can teach European science, we shall teach systems which by universal confession whenever they differ from those of Europe differ for the worse; and whether, when we can patronise sound philosophy and true history, we shall countenance at the public expense medical doctrines which shall disgrace an English farrier, astronomy which would move laughter in girls at an English boarding school . . . . The languages of Western Europe civilised Russia. . . . It is possible to make natives of this country thoroughly good English scholars, and to this end our efforts ought to be directed". Eventually, the victory was Macaulay's. The Government resolution of 7 March, 1835 stated:

" His Lordship in Council (Lord Bentinck himself was an anglicist) is of opinion that the great object of the British Government ought to be the promotion of European literature and science amongst the natives of India and that all the funds appropriated for the purpose of education would be best employed on English education alone."

The resolution did not go unchallenged. Due to the protest of orientalists, the Government slightly changed its

stand and gave some financial assistance to classical and vernacular teaching in the country. However, Macaulay's viewpoint prevailed and since 1835, scientific teaching in English has continued unabated in India.

Macaulay's minutes and the momentous decision of 1835 have been influencing the pattern of general and scientific education in this country even to-day in 1968. Therefore, the controversial topic merits further discussion. Macaulay was obviously ignorant, like many contemporary Indians and Europeans, of the by-gone glory of Sanskrit literature and Hindu Science. However, to be fair to him, it must be said that he did not lose sight of the probability of propagation of education through vernacular languages, which were admittedly underdeveloped and unsuitable for advanced and scientific education during his time. We must remember that in 1835, the standard of Bengali literature was low; people had yet to wait for Bankimchandra and Rabindranath. The problem of translation of classical and scientific works from English to vernacular languages was stupendous; there were not enough competent teachers amongst Indians; qualified British teachers could hardly be expected to master and teach in the vernacular languages. Macaulay clearly foresaw that English was destined to be the most important language in the international sphere. He did not clearly spell out another argument in his favour: English would be the natural common language even amongst Indians. We may argue to-day in 1968 that Hindi should replace English even in technical education, or that vernacular languages should be the ideal vehicles for mass education in literature and science; nevertheless, we have to admit that in view of the perspective in 1835, Macaulay's viewpoint was practical if not thoroughly justified.

Since 1835, vernacular languages continued to be neglected but liberal and scientific education in English progressed

through numerous schools and colleges. A large number of scientific organisations were established (see appendix). One hundred years after the battle of Plassey (1757), educational facilities in India were put on a sound basis through establishments of the universities of Calcutta, Bombay and Madras in 1857. Our nation and the people commenced to share the thoughts and aspirations of the pioneers of scientific education in this country.

CHRONOLOGY OF ONE HUNDRED YEARS' PROGRESS IN INDIA (1757-1857).

1757 Battle of Plassey.

1763 Medical Services introduced for British army in India.

1774 Birth of Rammohun Roy.

1781 Calcutta Madrasa founded by Warren Hastings. Calcutta Botanical Gardens established. Research on plant resources in India planned by James Kyd.

1784 Asiatic Society of Bengal founded by Sir William Jones.

1791 Sanskrit College of Benares founded by Jonathan Duncan.

1793 A School for Surveying established in Madras. William Carey arrives in Calcutta. Dr. William Roxberg starts research on Indian plant resources at the Botanical Gardens.

1796 A Meteorological observatory established in Madras.

1800 The Trigonometrical Survey of the Peninsula of India established; later expanded in 1818 to include topographical and revenue surveys. Foundation of Fort William College, Calcutta, one English School at Bhowanipur, Calcutta, and printing press at Serampore.

1805 Rammohun joins service under Digby and starts learning advanced literature in English..

1808 Asiatic Society Offices, library and museum were located at 1, Park Street, Calcutta.

1813 Charter Act grants one lakh of rupees per year for education and permits Christian missionaries to preach and teach in British India.

1815 William Carey composes a Bengali-English dictionary.

1817 Hindu College, Calcutta founded; scientific equipments for this College arrived from England in 1823.
Calcutta School Book Society founded.
Some geologists employed in survey work.

1820 Book Society formed in Bombay.
Agricultural Society of India established in Calcutta; transactions published since 1823.

1821 John Mack arrived in India as a missionary and started teaching and writing on Science.

1822 Medical education introduced in Calcutta Colleges; transactions published since 1825.

1823 The historic letter written by Raja Rammohun Roy to Lord Bentinck, pleading for Western and scientific education in India. Against his advice, Sanskrit College established in Calcutta.
Agra College founded.

1824 Meteorological observatory established in Calcutta. Commencement of elementary instructions in engineering at Bombay.

1825 Delhi College established on oriental pattern.

1826 Derozio appointed as a teacher in the Hindu College, Calcutta; injected liberal, critical and scientific thinking in his students' minds.

1828 English introduced in the Delhi College.

1829 "Gleanings in Science" periodical published first by James Herbert and then taken over by James Prinsep.

1830 Rammohun goes to England.

1833 Death of Rammohun Roy.
Birth of Mahendralal Sarkar.

1835 Foundation of Elphinstone College, Bombay.
Foundation of Medical College, Calcutta.
Adam's report, Macaulay's monutes and Lord Bentinck's resolution on future pattern of education in India.

1837 Foundation of Christian College, Madras.

1838 First medical hospital in Calcutta.
1839 A short-lived Mechanical Institute opened in Calcutta for imparting technical education to the Indians.
1840 An industrial school started in Madras.
1841 A Meteorological observatory established at Bombay.
Zoological and Anthropometrical research started in the Museum of the Asiatic Society.
Surveying department opened in Presidency College, Calcutta.
1844 Four Indians proceeded to England for training in Medicine.
Facilities provided for training engineers in the Elphinstone Institution, Bombay.
1845 Grant Medical College opened in Bombay. Its Surgical School of Practice received recognition from the Royal College of Surgeons in 1854.
1847 Engineering College, Roorkee, founded.
1848 The Students Literary and Scientific Society (Maharashtra) established.
1850 A country-wide network of railways began to be built.
1851 Madras Medical School raised to the status of College.
1854 Industrial Art Society established in Calcutta by Rajendralal Mitra.
An engineering school was founded in Poona.
1856 Bengal College of Engineering founded.
Foundation of the Indian Museum, Calcutta.
1857 University of Calcutta, incorporated, 24th January.
University of Bombay, incorporated, 18th July.
University of Madras, incorporated, 5th September.
Sepoy Mutiny, the first freedom struggle in India.

MAHENDRALAL AND THE CONTEMPORARY MOVEMENT FOR SCIENCE IN INDIA

With the establishment of the three major Indian universities in 1857, modern education gained its strong foothold in this country. This was the result of untiring efforts of many Indian patriots and European scholars and educationists. Along with liberal education, modern science continued to be appreciated by the Indians. Since the establishment of the Asiatic Society in 1784, many scholars (mostly European) investigated the flora and fauna of the sub-continent as well as archaeology, geology and meteorology of the country. Survey work and agricultural research were initiated in the twenties of the 19th century. Through the Hindu College and the medical colleges in India, rudimentary teaching in Physics, Chemistry, Mathematics, Anatomy and Medicine was imparted by the European scholars to the Indians. By 1857, foundation of engineering education in the country was laid ; this was necessary in view of the maintenance of the railway network started in 1850 and construction of roads and irrigation canals.

At Bombay and Delhi, attempts were made to impart scientific education in the vernacular languages. Since Macaulay's time, English was accepted as the only medium of scientific instruction. However, publication of scientific books and articles in the vernacular languages continued.

Particularly in Bengali, there were large number of science reporters and writers who could effectively disseminate scientific news and (what was more important) scientific thought to Bengali-reading public. Aukshoy Kumar Datta of the Tuttobodhini Patrika, Rev. Krishnamohan Banerji, and Rajendralal Mitra were the pioneers in popular scientific

writing in Bengali. They utilised their scientific knowledge even for expounding utilitarian doctorines. *

However, inspite of this nascent intellectual renaissance, scientific attitude amongst general mass of people left much to be desired. The attitude of common people towards science and scientists was best described in a mid-19th century periodical of our country :

"The man of science of to-day in India is looked upon by a very large number of Hindus as Friar Bacon in his day. Even the Asiatic Museum in Calcutta is popularly known as Jaddo-ghar or 'house of witchcraft', a name which is very probably given to every laboratory of science throughout the land. Now all this is of course very wrong and calls for correction." (Indo-European Correspondence, April 13, 1872, p. 200). Moreover, even most of the educated Indians felt that mere learning of science was enough ; they did not pay attention to cultivation or research in science, which after all had to be done by the Indians themselves, and could not be left to the European scholars in India. Mahendralal Sircar was the 'first apostle of scientific research by Indians' in our country. His work and speeches throughout nearly 40 years (1867-1902) amply illustrate the budding aspirations of the Indian people of his time in the realm of cultivation of science.

II

Mahendralal was born on 2nd of November, 1833 (this year, Rammohun had passed away) in a poor family of Paikpara, near Calcutta. Through great financial hardship, he pursued his early academic career at Hare School and then at Hindu College. At that time, Medical College offered

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* Aukshoy Kumar proposed an equation, which was a big step in modernism and utilitarianism in India:

Prayer + Labour = Agricultural Production
Labour = Agricultural Production
Hence, Prayer = O!

better curriculum in science courses. This attracted young Mahendralal who left Hindu College, against his friends' persuasion, and started learning Anatomy, Physiology and Medicine at Medical College. He graduated in the year 1860.

Mahendralal came to the limelight through his acquired interest and advocacy for the new system of medicine, Homoeopathy. In an early meeting of the Bengal branch of the British Medical Association (27th May, 1863), he had contemptuously alluded to Homoeopathy as one of the various systems of quackery. However, his contact with Rajendra Dutta and other Homoeopathy practitioners in the city gradually brought a change in his out-look. He observed the efficacy of the system, to the point that he began to support it. In the 4th annual meeting of the Medical Association (February 1867) he read a paper on "the supposed uncertainty in Medical Science and on the relationship between disease and their remedial agents". His support for Homoeopathy in this meeting caused consternation and disapproval amongst his erstwhile Indian and British friends. He was thrown out of the association.

Without entering into the controversy and arguments for and against Homoeopathy, it may be emphasised that Mahendralal stood for what he believed as truth. Even one of his opponents, Dr. K. Mcleod, a Professor and an eminent surgeon, wrote in December, 1902 :

"I am no admirer of Homoeopathy; but I verily believe that Dr. Sircar's espousal of Homoeopathy was honest and grounded on the belief that it furnished him with a fundamental scientific principle which placed medical practice on a higher plane. It required no little moral courage on his part at the time to break away from his teachers and fellows, and I honour him accordingly".

Mahendralal suffered throughout his career for adhering to his conviction. 'His nomination to the Faculty of

Medicine in the Calcutta University in 1878 was bitterly opposed by the physician senators who were "unable to associate themselves with a member who professes and practises Homoeopathy". Mahendralal was a true worshipper of truth and his courage and conviction was unflinching. He realised in 1867 that he needed a forum to propagate his point of view, and with this object, he started publication of 'Calcutta Journal of Medicine'. The Journal was well received in the city. Indo-European correspondence wrote on Feb. 1, 1868 (p. 59) :

"We desire to return thanks for the first number of Calcutta Journal of Medicine, edited by Dr. Mahendralal Sircar. We hope the new publication may meet with the success that it deserves. The editor's name is already very favourably known to the public for his candid, outspoken views on the subject of medicine". Later in the year, there was a friendly and humorous criticism (Aug. 1, 1868, p. 423) :

"If the learned editor will treat of homoeopathy, why will he insist on furnishing it to his readers in such un-homoeopathic doses?"

It gradually dawned on Mahendralal's mind that what was at stake in India was not simply Homoeopathy, but rational and unbiased thinking and assiduous cultivation of science. Throughout the next 35 years he tirelessly advocated the cause of scientific research to be done in India by Indians.

In the August 1869 issue of the Calcutta Journal of Medicine, Dr. Sircar published an article entitled, "The desirability of a national institution for the cultivation of the physical sciences by the natives of India". In the historical letter of 1823, Rammohun had pleaded for scientific education in India; in this equally significant article of 1869, Mahendralal desired that Indians should cultivate and advance the physical sciences. Mahendralal observed in the article :

"The Hindu mind has lost much of its original Aryan vigour and energy and has become more of a speculative than of a practical character, singularly deficient in patient industry to observe and collect materials, too prone to hasty generalisations, depending more upon its own inspirations, than upon outward facts. Thus, though highly endowed, it has been little productive of results".

Referring to the above mentioned article and the subsequent pioneering activities of Mahendralal, Rev. Father Lafont another pioneer in Indian Science remarked :

"Dr. Sircar, seeing that the superiority of the Western nations was mainly due to their knowledge of Science, wanted to diffuse that knowledge among his countrymen, in the hope that after mastering what had already been discovered by the Europeans, the Hindus might in the course of time, add their own discoveries to those of their fellow brethren in the West". The 'Statesman' commented : "A new era dawned on this country when Dr. Sircar published and resolved to act upon his conviction, that the only method by which the people of India can be essentially improved is by cultivation of the physical sciences".

Mahendralal derived ideas and inspiration from 'Royal Institution' (founded 1799) and 'British Association for the advancement of science' (1831). It is likely that he closely followed the activities of Charles Babbage, the founder of the British Association, and his followers in England. He might have been influenced by Babbage's book, "Reflections on the decline of Science in England" and his successful indoctrination of the British masses in the scientific way of thinking.

Dr. Sircar stirred public mind with reference to his scheme for an Indian institution of science, elaborately planned out in 'Hindu Patriot' (3rd January, 1870). Father Lafont had already started his famous popular lectures on

science at St. Xavier's College. Gate collections in this series of lectures (June 2, 1870 and onwards) were handed over to Mahendralal. Princely donations were obtained from Maharajas of Vizianagram, Coochbehar and Patiala, Maharani Swarnamoyee, Kalikrishna Tagore, etc. Mahendralal realised that the success of his project depended on generous co-operation from the Government as well as the rich people of the country; his appeals were directed to both the sectors. In a lecture delivered at Medical College on 1st of February 1871, he commented:

"It would be a shame if the elaborate and generous system of Government education were to result in a generation incapable of appreciating the revelations of Science".

At that time, only St. Xavier's College under the leadership of Father Lafont offered modern and effective teaching in Science. The situation was different in Presidency College. According to Mahendralal, there were a few scientific equipments in Presidency College "not for use but misuse and disuse". Not until the arrival of Sir Alexander Pedler as a lecturer in Presidency College, the science programme in the College could be revitalised.

Referring to the lectures delivered by Father Lafont and Mahendralal at the Medical College on 11th of April 1872, the Indian Mirror remarked:

"It has struck us not a little remarkable that with so much accommodation given to the students of the Presidency College, for pursuing the study of the physical science with a professor and an expensive laboratory to boot, few of them are seen to evince a living interest in the cause of Science". The inference drawn was that the policy for scientific teaching had to be revised and that the Government had to spend more attention in this direction. Henry Woodrow, the then Inspector of Schools of Bengal had remarked that Indians were lagging in scientific education and research.* The great

Bengali novelist Bankimchandra quickly retorted in his periodical 'Bangadarshan' suggesting that Henry Woodrow would better help the cause of Science in India by enlisting moral and financial support of his countrymen towards Mahendralal's scheme

Bankimchandra also supported Mahendralal's caustic remarks about the miserliness of the Indian rich people (except a few who had contributed to the fund) The list of donors was published with the comment that it was a remarkable document in so far as it did not contain the names of some of the conspicuously rich Indian people.

Much later, Mahendralal made his famous comment (July 30, 1895)

"We have two kinds of hoarded wealth in this country — one in the shape of the gold and silver and the other in the shape of intelligence In order to liberate the latter, it is necessary to liberate the former, which in this sublunar World of ours is a magic transformer of all kinds".

It was as a result of all these insinuations, agitations and persuasions that donations came pouring in the begging bowl Sir Richard Temple, Lieutenant Governor of Bengal, inspired by Mahendralal's mission, approved in his note on 21st of January 1876 that the Government decided to donate a house (without furniture) near the crossing of College Street and Bowbazar Street in Calcutta, to be used as the office and laboratory of the projected Science Association. By 1875, Dr. Sircar had collected over eighty thousands of rupees as donations. On March 13, 1876, the foundation of Lecture Hall of the 'Indian Association for Cultivation of Science' was laid; Sir Richard Temple formally inaugurated the Association on the 29th of July, 1876, at 210, Bowbazar Street, Calcutta. This was the first Indian institute for scientific research, the forerunner of a chain of national laboratories in our country.

III

The history of movement for scientific research in the nineteenth century India would remain incomplete unless the thoughts and activities of Mahendralal's contemporaries are specifically mentioned. Apart from Krishnadas Pal, Vidyasagar, Bankimchandra and Keshabchandra who assisted Mahendralal in many ways, three personalities made major contributions towards the advancement of science in our country : Father Lafont, on whom a separate article shall follow, Abdul Latif Khan and Rajendralal Mitra.

Nawab Abdul Latif Khan was one of the very few Muslims educated in the Western style before the Sepoy Munity of 1857. He noticed how the Hindus were progressing through the benefit of Western education and felt that Muslims should also follow the same path of enlightenment. He declared a prize in 1863 for the best essay in Persian on "How far would the inculcation of European Sciences through the medium of the English language, benefit the Muhammadan students in the present circumstances of India, and what are the most practicable and unobjectionable means of imparting such instruction?" The same year, he established Muhammadan Literary Society with the object of promoting liberalism and science-consciousness amongst Muslims.

Indo-European correspondence reported on Sept. 10, 1870 :

"Moulvie Abdool Luteef Khan, whose endeavours to excite a healthy appetite for art, literature and science among Muhammadan community are well-known, secured the services of Rev. Father Lafont to deliver a lecture on September 7, 1870, evening, the fifth monthly meeting of the Muhammadan Literary Society, on the 'Main Properties of Fluids'. Moulvie acted as an interpreter to the elite of the Society".

Rajendralal Mitra born on 1822 was a pioneer in popularisation of Science in Bengali. Through the periodicals : Vividartha sangraha', 'Rahasyasandarva', 'Tuttobodhini' etc.,

he strived to nourish the scientific curiosity of Bengali-reading public. His particular interest was in the earth-and life-sciences. In 1877, he wrote an article on "A scheme for the rendering of European Scientific terms into the Vernaculars of India". On the 6th of April, 1854, he had founded "Industrial Art Society' where the Indians could systematically learn the techniques of carvings on wood, stone and metal. Like Moulvee Abdul Latif Khan, he also tried to disseminate scientific thinking amongst the masses. He used to invite speakers on Sciences in the Burrabazar Family Literary Club of which he was one of the founders. On the 10th of April, 1876, Father Lafont delivered a lecture on 'Electricity' in the club emphasizing the magnetic and dynamic effects of electricity. The concluding remarks made by Rajendralal Mitra after Father Lafont's speech demonstrate his unique grasp and foresight over the subject and the future role of science in our society:

"The time is not far distant when Electricity, in the form of magnetism, will replace our steam locomotives and drag our railway cars. The little magnetic instrument exhibited by the lecturer may appear as a toy, but the rapidity with which you have seen it turn, will under proper management, ere long, prove as efficient a motive power as steam." It is no wonder that Abdul Latif Khan and Rajendralal Mitra gave unstinted help to Mahendralal in the establishment of the Science Association.

While Mahendralal was in favour of an institution where fundamental scientific research could be done, quite a few leading citizens of his time felt that public and private efforts and resources should better be directed towards improvement of facilities of technical education. This controversy vis-a-vis basic scientific and applied technical education needs some clarification. Technical education was introduced in this country by the Britishers themselves at first in Roorkee, Cal-

cutta, Bombay, Poona and Madras. Quite a few Indians were impressed by the practical benefits of learning science. They were primarily concerned with the economic betterment of the masses; an obvious panacea for this was technical education and industrial growth in the country. It has been mentioned that Rajendralal Mitra established Industrial Art Society in 1854. Keshabchandra founded a technical school (on the 28th of November, 1870) where facilities were provided for teaching of carpentry, watch-repairing, lithography, engineering etc. This practical approach was readily accepted by the leaders who placed greater emphasis on the social and economic uplift of the country. Reverend Krishnamohan Banerji (a pupil of Derozio) an early pioneer of scientific writing and the President of 'Indian League' founded in 1875, as well as Sisir Kumar Ghosh, the Editor of Amrita Bazar Patrika, championed the cause of technical education as opposed to the liberal and scientific education proposed by Mahendralal. They founded 'Albert Temple of Science' on the 28th April, 1877.

A large majority of public and press supported 'the idea of a fusion of the two schemes into one, which is most likely to command success by unity of efforts and sufficiency of funds'. Sir Richard Temple proposed an amalgamation of the two societies. Mahendralal and Father Lafont emphasized clearly "that the principles of Science must be taught first before they could be applied to the teaching of practical art". Krishnamohan and Sisirkumar did not agree and wished to stay apart. Due to lack of popular support, Albert Temple of Science and its scheme for technical education never functioned properly.*

* In 1905, when National Council of Education was established by Tagore and other patriotic leaders, Motilal Ghosh of the Amrita Bazar Patrika offered to the Council Rs. 4,500 on behalf of the Albert Temple of Science with the purpose of promotion of technical education.

The perseverance of Mahendralal prevailed and his scheme enlisted increasing popular support day by day; however the controversy continued till Mahendralal's death. In the 24th meeting of the Science Association, (5th of September, 1901), Dr. Sircar said :

"Educated patriotic gentlemen are wasting their energies in the vain endeavour to promote technical education without even thinking of the absolute necessity of a preliminary scientific education. And patriotic editors have not been wanting who have denounced in no measured terms your humble servant for not having given his consent to convert this institution into a technological institute; as if his consent without adequate funds was all that was necessary to start a full-fledged institute for the initiation of our young men in the mysteries of all the arts and industries" !

It has to be emphasized that Mahendralal was not against technical education as such ; he was simply pointing out (rightly, and for the first time in our country) the necessity of scientific education to serve as a broad-base for technological training. It might be further argued in support of his point of view that technical skill was never lacking in India and one of the reasons why technology never progressed in the middle ages in our country was that there was no fundamental science to back it up.

IV

The success of Mahendralal's project was due to his tremendous conviction and tireless efforts. His up-to-date knowledge and command over science, and persuasive power prevailed over the most enlightened ones in the country. One incident may be narrated to illustrate the point. While Lord Lytton was the Viceroy of India, Dr. Sircar on being invited, went to the Government House and explained to him the actions of Crookes Tubes. A contemporary report says :

"It is not possible for any individual to forget the evening. Dr. Sircar had such a wonderful mastery over the subject that he very easily explained the amazing behaviour of one millionth of atmosphere to the entire satisfaction of His Excellency. Two eminent European professors of science were present there and they directed their arguments in a sophisticated way against Dr. Sircar. They had no belief in the bombardment of ions. But the wheels of mica placed at forty five degrees revolved like a well-conducted machine. That was the triumph of science".

We may continue with the story of Science Association at Bowbazar Street. Funds gradually swelled, a lecture hall was built on the 13th March, 1882, precious scientific equipments were bought (those were "superior to even the equipments at St. Xavier's College") and a research laboratory was founded on March 29, 1890. Popular lectures continued to be delivered by Mahendralal and Father Lafont in Physics, Taraprasanna Roy in Chemistry and Father Penaranda in Astronomy ; and later by Kanailal Dey, Chunilal Bose, Ram Chandra Dutta in Chemistry, Pramathanath Basu in Geology, Sashibhusan Mitra, Banwarilal Chowdhury and Girish Chandra Basu in Biological Sciences and by Sir Ashutosh Mukherji ("mathematician spoiled in the Court"—Mahendralal) in Mathematics.

A climate for advanced studies and research in science had been created. When Sir Alexander Pedler joined Presidency College in 1873, he had already brought modern scientific equipments for the purpose of advanced teaching. Through the efforts of Pedler, Lafont and Sircar, an alternative B.A. Course in Science was approved and accepted by the Senate of the Calcutta University. In 1886, there was a suggestion afoot from Mr. Tawney of the Calcutta University, backed by the Government that technical education should be introduced at the school level and the institu-

tions which would not arrange technical education would cease to receive Government aid. Father H. Neut, the Rector and other Jesuit teachers of the St. Xavier's College opposed this imposition. Father Neut subscribed to Mahendralal's view that technical education though extremely necessary was meaningless without the broad base of fundamental science. He said : "To begin the technical studies in the school itself is to prepare a generation without elevation or grandeur" (Indo European Correspondence, p. 780, 1886). In 1893, the Science Association was affiliated with the Calcutta University; the teaching in the physical sciences imparted in the Association was regarded as adequate for preparation of the university examination.

During the last two decades of the nineteenth century, leadership in Science came in the hands of two pioneer scientists in India who had just started their long teaching and research career at Presidency College; Jagadis Chandra Bose and Prafulla Chandra Ray. Both of them were actively connected with the Science Association of Mahendralal. However, they spent most of their time in Presidency College with the students and amidst their research activities—this only gladdened the heart of Mahendralal. Referring to the success of Jagadis Chandra's pioneering research in wireless telegraphy, Mahendralal remarked (19th August, 1896) :

"I can scarcely express in words the delight I feel at his success and I sincerely tell you that that delight could not have been greater than if he had been my own son, or if I myself had been in his place. . . . I am rejoicing much more simply because he has shown that Indians are not mere speculative and unpractical dreamers, but that they can, if they but will it, be as practical as any nation on the face of the globe".

The people and the Government had shown tremendous enthusiasm in the Indian Association for Cultivation of Science

when it was founded. By the closing years of the century however, the response to the plea for financial help and donations was getting poorer and poorer. The schemes for more equipments, research professorships and scholarships etc. could not be implemented for the lack of funds. This threw Mahendralal into a state of great desperation and despondency. His last few addresses at the Science Association were "pregnant with the heart-rending ring of a swan song".

In April 1899 (22nd Annual meeting of the Association) Mahendralal said :

"From the very beginning, I have been telling you that in order to enable the Association to do its legitimate work : that of research, you must have men devoting their whole time and attention to special subjects and that you *must provide for them*.... While we are sleeping over our oars, a Sister Presidency (the project of Indian Institute of Science, Bangalore by Sir Jamshedji Tata) has startled the country by what appears to be a new scheme involving an outlay calculated to tax the resources of an empire. Neither the scheme nor the estimate for carrying it out is new. I have been giving out my views of both whenever I could get an opportunity for doing it".

On August, 30, 1900, he continued : "Owing to some malefic influence of stars, for I cannot otherwise account for the strange niggardliness the wealthy and the enlightened have displayed in this matter, the necessary funds for the endowment of Professorships were not placed at our disposal, and we have *lost at least two decades of time*".

Mahendralal had a superb historical perspective; he predicted in as early as 1888 :

"The ultimate success of my scheme will depend upon the fact of its being a *national movement*". He was sure that the national movement will succeed sooner or later.

On Sept. 5, 1901, he lamented :

"I had hopes that even during my lifetime I shall have the gratification of seeing the Association flourish as has done the Royal Institution, on the model of which it was founded and that if not myself, some of you would be able to make *some addition* to the stock of knowledge and thus take part in the grand intellectual movement which is going on throughout Europe and America".

A sense of frustration and anguish was the theme of his speech on Sept. 4, 1902 (25th annual meeting) :

"I have failed in fulfilling a task which I had imposed upon myself, and for which I had solicited your co-operation. Co-operation I have had, but co-operation of a few only, of scarcely over a hundred out of hundreds of thousands of my educated countrymen, out of sixty millions of Bengal, and if you like, out of three hundred millions of India, for it was my ambition to make the project entirely national, embracing the whole continent with its diverse races and peoples...."

Mahendralal passed away on the 23rd of February, 1904. Three months before his death, he bade farewell to his colleagues of the Association (26th annual meeting, 26th of November, 1903) and in the letter reiterated his firm conviction for the cause of Science in India and hope for its success :

"I have only now to reiterate my conviction that if our country is to advance at all and take rank and share her responsibilities with the civilised nations of the world, it can only by means of Science or positive knowledge of God's Works".... His last words were : "I bid you all, and you, in particular, Reverend Father (Lafont, who was in the chair of the meeting), without whose ungrudging and long continued aid the Assaciation could never have been an accomplished fact, I bid farewell".

The hopes and ambitions, disappoinment and forbearance and above all an acute concern for scientific progress in

India as reflected in Mahendralal's words epitomised in a way the similar feelings of the like minded thinkers of his time.

'New India' commented in its editorial on September 11, 1902 :

"We cannot ignore the sad truth that while on the one hand, the Science Association stands as memorial of Dr. Sircar's energy and his profound love for his own country and own people, it is a disgraceful commentary on our national character on the other. As long as the Viceroys and Lieutenant Governors openly supported this movement, money came from all quarters to its funds, but with *the practical withdrawal of official patronage*, the purse strings of the wealthy public tightened at once, which not even the magic of Queen Victoria's name could reopen".

Apart from the denouncement of the understandable apathy of wealthy people, the patriotic resentment against the Governmental apathy was also underlined in most of the press comments.

'Voice of India' published an editorial entitled, "Our public spirit, so called" on September 27, 1902. This editorial was full with contemporary patriotic vigour and socio-political thinking :

"So my good friend (was the writer Dadabhoy Naorojee himself?) Dr Mahendralal Sircar has grown despondent. Why should he ? He has tried his best all his life to bring home to his countrymen the benefits of true science and of scientific education. It is no fault of his and of his colleagues like Father Lafont if the Association has remained unappreciated by the generation for whom they have worked so devotedly. Appreciation is bound to come with true education; meanwhile our public workers must possess their souls in patience.

"But from whom did the promoters expect substantial aid for the Association ? From a *short-sighted and a slovenly*

foreign Government ? Or, from an apathetic and besotted aristocarcy in the land? Or, from an illiterate and half-starved peasantry ? The educated progressive class in the country ought to have been their main support—the professional, commercial, industrial aristocrats of India those have made their fortunes through, and who have been able to enjoy them under, a settled rule. Has this particular class been duly reached by Dr. Sircar ? I should like him to make one supreme effort in this direction; if he succeeds, he may yet shame the authorities into recognising the claims of the Association in an adequate measure".

Clearly, the movement for Science in India had reached a new stage. Industrialists like Sir Jamshedji Tata and patrons like Taraknath Palit and Rasbehari Ghose etc. were to play leading roles after the death of Mahendralal. Besides, the movement for Science could no longer be dissociated from the socio-political situations in the country and the nationalists like Sir Ashutosh and Madan Mohan Malaviya were destined to fight for securing stronger foothold of scientific education in the country.

Nevertheless, the biggest and the most glorious outcome of Mahendralal's efforts was in the commencement of scientific research in India by Indians Apart from Jagadis Chandra's and Prafulla Chandra's pioneering scientific activities, mention must be made to the initiation of research programme in the Science Association itself in the first decade of this century. Dr. Sarasilal Sircar made useful investigation on the 'Crystallography of Copper ferrocyanide' (1902); at the same time a team of research workers investigated problems on food and nutrition under Dr Chunilal Bose; Dr. Rasiklal Dutta conducted research in Chemistry.

In 1907, the famous Indian scientist, Sir C. V. Raman came to Calcutta as an officer in the Government Dept. His scientific background acquired at Madras, and tremendous

zeal for scientific research led him to start investigation on acoustics at the Science Association. His paper published in Nature, 24th October, 1907 gained him considerable scientific reputation. Amritalal Sircar, son of Mahendralal remarked in 1907 :

"Mr. C. V. Raman is now in the Finance Department for his livelihood and what an amount of energy is lost there! If you my countrymen, could provide for such intellects then what a rich harvest would you have reaped from them". Sir Ashutosh appointed Raman as Professor of Physics in the Calcutta University in 1917. Even afterwards, the Science Association continued to be the venue of the world famous experiments on optics by Raman and his students. Later Krishnan, S. K. Mitra, Meghnad Saha and many other famous Indian scientists became associated with this institute —the crowning glory of Mahendralal.

When Sir C. V. Raman was awarded the Nobel prize in 1930 for his earlier discovery of 'Raman effect' (1924), he gratefully recalled the pioneering role of Mahendralal :

" I have always felt that the Indian Association for cultivation of Science is my proper home ... Dr. Sircar had sown the seed and it has fallen to my lot to reap the harvest".

It can be truly said that Mahendralal was the first apostle for scientific research in modern India. Father Lafont commented after Mahendralal's death : "Dr. Sircar was a man such as you find seldom in large communities, even in Europe". His integrity, vision and love for Science comparable to those of Roger Bacon in England, heralded in India an era of scientific research and researchers.

REV. FATHER LAFONT OF ST. XAVIER'S COLLEGE

Pandit Shibnath Sastri remarked in one of his writings that the period from 1856 to 1861 had been a very significant one in the context of Indian Renaissance. Eminent Indians like Jagadis Chandra Bose, Bipin Chandra Pal, Rabindranath Tagore etc. were born in this period ; widow remarriage movement, Indigo movement and Sepoy Mutiny agitated the mind of young India ; and in the turmoil, everlasting benefit was done to the country in the establishment of the three important Indian Universities in the year 1857.

16th of January, 1860 was a very important date in that epoch-making age ; for on that day, St. Xavier's College was started at the site of *Sans Souci* Theatre at Park Street in Calcutta. How the college has influenced the Bengali and Indian mind throughout one complete century is a long tale, only a part of which may be told in this article. The life and works of Rev. Father Eugene Lafont S. J. (of the Society of Jesus) would be particularly discussed here, he having been not only one of the chief architects of the Xaverian tradition but also a pioneer of Indian science and fittingly called the "Father of Science in Bengal".

The history of the earlier St. Xavier's College that ran its chequered and strenuous course from June 1, 1835 to Sept. 27, 1846 is known to but few. The college was opened in the interests of Catholic education and was conducted by the English Jesuits. On account of the Protestant rivalry and party feelings running high even amongst the Catholics of Calcutta, the first St. Xavier's College had to eventually close down its book. The Catholics of Calcutta petitioned the Holy See for a good college to suit their purpose and this time, the task was taken up by the Belgian Province of So-

ciety of Jesus. The first batch of eight Jesuit Fathers led by Father H. Depelchin arrived at Calcutta on Nov. 28, 1859. In the meantime, the old *Sans Souci* Theatre at 10, Park Street (at present 30, Park Street) had been bought by the Catholic community and this building came to be the site of St. Xavier's College.

The College started very modestly on January the 16th, 1860. Under the management of Father Depelchin and patronage of devoted Catholics like Mr. James Cantopher, Mr. Bentham Bowring (Private Secretary to Lord Canning) etc., the College gradually grew up to its full stature. It was soon affiliated to the Calcutta University. Inspite of sickness, opposition, financial difficulties and "perhaps because of all these, God's work prospered". In this background, the arrival of Father Eugene Lafont at Calcutta on December 7, 1865 was an auspicious event ; for besides being one of the pioneers of Science in this country, he guided the course of St. Xavier's College through 43 long years ; he made the Xaverian edifice at Calcutta nobler and stabler. Although Father Lafont and St. Xavier's College were indissolubly connected, we propose to focus our attention on Father Lafont and to probe as regards how his words and deeds glorified the College, he represented.

II

Eugene Lafont, eldest son of Pierre Lafont, was born at Mons in Belgium on the 26th March, 1837. Father Lafont, in his maturity did not remember much about Mons and the house and street where he was born, for it was "so far back" and he had seen "so many others since". As a matter of fact he had hardly stayed at Mons. His early training was at Ghent (St. Barbara's College) where his father was an Army officer. Very little is known about Fr. Lafont's boyhood. He joined the Society of Jesus in De-

cember, 1854. After the preliminary training afforded by the order, he gave himself to the study of Philosophy and Natural Science at Namur. Father Depelchin was at that time Minister of the Namur College. It was here that he developed that aptitude for Experimental Physics which in him seems to have been a real gift and which he utilised to such immense advantage in later years and in other climes. His service was very soon requisitioned for Bengal Mission and he came down to Calcutta in the winter of 1865, and joined St. Xavier's College.

In 1866, he was engaged in the Pre-entrance class but very soon he had to teach Natural Sciences in the College. It was during this year that Father Lafont gave the first of the long series of public exhibitions that ended only with his death 42 years later. "It was a very humble beginning—only a magic lantern show. He worked the slides but owing to his want of the familiarity with the English language, he engaged the services of one of the senior boys, Richard Bradley, to announce the pictures". Charity is said to begin at home and Father Lafont gave the doses of scientific thought to his own pupils first before trying the same on the Indian public. Besides, he had to wait till the public was acquainted with his name; and the cyclone of 1867 gave the opportunity.

He had been steadily acquiring apparatus for his physical laboratory ('Museum' as he called it) and day-to-day meteorological observations. With his meteorological apparatus, he sensed an approaching cyclone in the morning of 1st Nov. 1867 and gave the timely warning to the Government Meteorological Department. The cyclone came that night obeying his predictions. He took series of meteorological readings braving the fury of elements, and published the same. The newspapers had rather disparaging comments on the fact that "the Government observatory had failed to do

what the scientific enthusiast had braved the elements to perform". The public came to know of this unique man, who had come in this country to preach not only religion but also science. Father Lafont continued his scientific pursuits and particularly meteorological ones. In 1870, Secchi's meteorograph, a self-registering instrument for recording temperature, pressure, rainfall, velocity of wind etc. was purchased and placed in the Physical Laboratory of the College for daily observations. The cogent recordings of the weather in its multiplicit forms and its publication in the form of tables made Father Lafont and his laboratory very famous, not only in this country but even abroad. Abbe Megino, the French Savant said: "These are magnificent tables. We offer Father Lafont our best congratulations. He does better than the Imperial Observatory of Paris".

Now that his popularity in the city was an established fact, his lectures at the College Hall drew ordinary public and the college gatherings underwent a metamorphosis into public lectures. On Sept. 18, 1868, he gave a public lecture on a scientific subject which was favourably commented upon by the local press. The demonstration "showed clearly how attractive a really good course of popular scientific lectures, abundantly illustrated with experiments would be to the inhabitants of Calcutta". The series of lectures in the months of May and June, 1870 were similarly appreciated. It was reported about the lecture on 19. 5. 1870, that "notwithstanding rain and lightning, a pretty fair attendance of native gentlemen gathered around the lecture table to hear the exposition of Dalton's atomic theory and witness some experiments, illustrating the general principles of matter........ Throughout the series, the gentlemen were most assiduous and punctual in their attendance".

Father Lafont continued his popular scientific lectures till his death in 1908. The reader need not be bored with a

huge catalogue of references. The fact however remains that he was a successful populariser of science and this was due to his beautiful introduction and presentation of the topic. He knew how to "sell his wares". In a lecture on X-ray, he would start with a claim that a particular shoe-maker makes the best kind of boot and then he would proceed to show how the superiority over other kinds of boots may be established by X-ray experiments. Late Rev. Father A. Briot S. J., who had seen Father Lafont, told the author in 1959 that the lectures of Father Lafont had always a novel beginning and an ending with an exclamatory note on 'God's beautiful positive works'. While his religious preachings drew Catholic devotees round him at St. Thomas Church in Middleton St., his scientific lectures equally fascinated the architects of scientific renaissance in Bengal. Dr. Mahendralal Sircar, the eminent homoeopath and founder of Indian Association for Cultivation of Science was strongly attracted by the scientific preachings of this man of God and became tied to him by a life-long friendship. The two friends then proceeded to sow the seed of science in the fertile land of Bengal.

III

The historic letter of Raja Rammohun Roy addressed to Lord Amherst advocating for introduction of scientific education in India had marked the beginning of a new age. Although the Raja's dream was not fulfilled in his life time, it gradually came out to be true. It was left to Mahendralal to launch the crusade for scientific research in India. The idea of a Science Association where Indians could do original research work and cultivate science in its various aspects occupied all thoughts and efforts of Dr. Sircar. The project of the Association was conceived and given out in December, 1869 (when Father Lafont had already started his public lectures) and it was not till after "six years' agitation, cogi-

tation and education of public mind" as Kristo Das Pal used to say, that the Association was opened for work in 1876. The leading men of the then Bengal *e.g.* Keshub Chandra Sen, Vidyasagar, Bankim Chandra, Kristo Das Pal etc. came forward to help Dr. Sircar to the best of their abilities. His Grace the Archbishop Goethals and the professors of St. Xavier's College, who were representing Catholic opinion through the forum, "Indo-European correspondence" (later "Catholic Herald of India") did not lag behind. On the one hand they encouraged and instructed Father Lafont in his noble venture of popularisation of science and on the other, they recommended Dr. Sircar's project of Science Association strongly to the public*.

The acquaintance and friendship between Dr. Sircar and Father Lafont (which happened perhaps in the year 1869) must be admitted as a very significant event in the scientific renaissance of the country**. While most of the others helped the cause of science in India by mere 'agitation' and 'cogitation' the patient task of educating the public mind was taken up by Father Lafont. At the time the funds of the projected Science Association were swelling by the donations of Maharajahs and wealthy men, the humble gate collections of the public lectures of Father Lafont were also added to it. On 2nd June 1870, Father Lafont delivered his first lecture towards the cause of the Science Association, at St. Xavier's College.

The discourse of Father Lafont on the 'Physical Basis of Spectrum Analysis' delivered on 11th April, 1872 at the Medical College stirred up the public mind greatly in favour of propagation of science. The comments of "The Indian

* Ref. Indo European Correspondence, Sept. 26, 1868, May-June issue, 1870, March, 1882 etc.

** Prof. Meghnad Saha used to say, "They always worked together."

Mirror" on the said lecture may be quoted as this amply proves what the joint personality of Father Lafont and Dr. Sircar meant to the intelligentsia of the nineteenth century Bengal.

"For the space of two hours, Father Lafont kept up the interest of his audience by the fascination of his discourse as step by step he traversed the grand field and carried us through the mysteries of the distant worlds.........There was an electric effect produced by the lecturer's words, which were at once clear and graceful, plain and animated, rising at times to the height of eloquence.

"......Time has come when someone ought to take the missionary's role and go through the country interesting the people by means of popular science lectures and exposition of the kind given by Father Lafont."

"There can be no doubt that Father Lafont and Dr. Sircar are *the persons to whom the popular vote would turn in the matter of the choice for leaders.* It is to them, therefore, that all our hopes in this direction are directed". (Italics are mine).

When the Science Association was founded, Father Lafont used to deliver lectures at the Association premises every Thursday evening. In Father Lafont's own words, "Thursday was my only day of leisure in the week and although I had a great deal of work in the preparation, I was amply repaid by the manner in which my lectures were always attended and received". After long 19 years, Father Lafont had to discontinue his lectures at the Science Association but his contact with the Association remained as fresh as ever till he breathed his last.

In the year 1893, the Science Association was affiliated in the Physics and Chemistry course of Calcutta University upto the 1st Arts standard.Before that, the members of the Association had doubted whether a Research Association should take up teaching and beg for affiliation under an University.

It was Father Lafont who at that time convinced Dr. Sircar and others "that as one of the objects of the Association was the diffusion of knowledge of science by lectures, and as from the funds at the disposal they were only to fulfil that subordinate object, it would be no derogation of its dignity to seek the affiliation". Fourteen years later (in 1907), the same Father while presiding over the Annual Association meeting (Sir C. V. Raman was present in the meeting; Dr. Sircar had died three years earlier) approved the idea of disaffiliation as the Association had funds and abilities for pursuits of research and as the task of science-teaching could now be left to the competent authorities of the private colleges. While in his death bed, Dr. Sircar rightly referred to Father Lafont "without whose ungrudging and long continued aid the Association could never have been an accomplished fact".

IV

In October 1871, Father Lafont was appointed Rector of St. Xavier's College, and his position as head of the college naturally afforded him wider opportunities for furthering the interests of the institution. Even before he was raised to the Rectorship, he was endeavouring to impart real scientific instruction to his pupils. In the letter dated 21. 4. 1870, addressed to Mr. W. S. Atkinson, Director of Public Instruction, Father Depelchin wrote :

"Three times a week, lectures on the attractive and useful science are delivered to all students of the college Department by the Rev. Father Lafont. The lectures are illustrated with experiments". Although the attendance was compulsory, the students liked it. They always found interest in the lectures and in the latest apparatus secured by Father Lafont.

Father Lafont was always the first to exhibit the latest discoveries of physical science to his students as well as to the

Indian public: Telephone, Tesla's experiments, Wireless Telegraphy * X-ray, coloured photography, Phonograph, the phenomena of Radioactivity etc. are some of the examples. Generations of students listened with the same enchantment, as their elders did before them, to the wonderful lectures of this wonderful man. "Many a college feast day had its pleasant termination in the laboratory as the good Father had the habit of taking the school around him in the Museum".

An ardent believer of experimental science, Father Lafont expanded his physical laboratory as best as he could. This laboratory was a 'cynosure of all eyes', whether in India or elsewhere. Wealthy people donated for the purchase of new instruments. In January 1872, Lord Mayo presented to Father Lafont a beautiful model of horizontal steam-engine. From the Paris Exhibition (1900), the Father collected a good stock of some latest apparatus.

The most important event during the first Rectorship of Father Lafont was erection of the Astronomical observatory of the college, the history of which may be briefly told. On December 9, 1874, the transit of Venus across the Sun's disc aroused the enthusiasm of the astronomers throughout the world. Prof. P. Tacchini, the famous Italian Astronomer had arrived in India and invited Father Lafont in the Muddapore expedition. Father Lafont participated and later published an intersting account of the expedition and its results. ** Prof. Tacchini was so impressed by the value of solar observations in the cloudless sky of India that he persuaded Father Lafont to erect a spectro-telescope at St. Xavier's. An appeal

* After Sir J. C. Bose, a student of Father Lafont had made the discovery, it was the great Father who insisted on his celebrated student, that the discovery should be demonstrated in public.

** With the help of a spectro-telescope, Prof. Tacchini made the important discovery of the presence of water vapour in the atmosphere of Venus. The total time of transit, as noted by Father Lafont with the help of equatorial refractors and carefully rated chronometers, was 4 hours 41 minutes, 1.5 seconds.

was made for funds; Sir Richard Temple, the then Lieutenant-Governor visited the college on 5th February 1875 and granted Rs. 2000/- for the purpose. Four days later, Father Lafont approached Asiatic Society of Bengal, of which he himself was a member, for "monetary help. The society granted Rs. 500/-. A total of Rs. 21,000/- was soon amassed and orders for the necessary equipments were placed to various European firms. A magnificent circular flight of steps led up to the observatory which was placed 60 ft. above the ground. The important equipments were as follows : a large equatorial, a parallatic instrument, object-glass of which was furnished with an hour-circle; six astronomical eye-pieces, five micrometer eye pieces, one ring micrometer; a clock work with conical pendulum; a direct vision spectroscope and lastly a polarising helioscope with photometer. It took 18 months to construct the whole instrument. Father Alphonse de Penaranda, an able colleague of Father Lafont, calculated the geographical co-ordinates of the site of the observatory *. The work of daily mapping of the solar protuberances, study of sun's spots, and studies of other heavenly bodies were started; even to-day, the Jesuit Fathers of the college are busy in important astronomical observations. Father Lafont's astronomical work was pioneering indeed as the Govt. of India decided, almost simultaneously to erect an observatory at Kodaikonal.

In view of the remarkable contributions of Father Lafont in the educational field, suggestions were afloat in the year 1876 that the Father should be nominated a Fellow of the Calcutta University. The Statesman wrote, "The University would gain more honour by the nomination than Father Lafont". The Father was eventually nominated a fellow in March 1877 and ever since he took active interest in the

* The values viz. Longitude East of Greenwich 5 hrs. 53 min. 26 sec. and latitude North 22° 32' 51", are greater than those of Alipore observatory by 6.23 secs. and 45.8" respectively.

affairs of the university. It was mainly due to him, Dr. Sircar and Sir Alexander Pedler that the importance of scientific study in the university curriculum came to be recognised. His advocacy for more stress on science and experimental science in particular and more laboratory facilities in the colleges convinced the members of the Indian Universities Commission, appointed in the year 1903. His suggestions for an improved science course were accepted and eventually implemented by the university.

V

The varied engagements and tireless activities at the St. Xavier's college, Science Association, Asiatic Society of Bengal and the Calcutta University broke down the health of the Father and he had to abandon his Rectorship and go to Europe for recovering the lost health (1878). He returned the next yaer and continued not only his lectures in Natural Science but also all other former activities. In 1901, he accepted his second Rectorship for another three years. His health having broken irrecoverably, he had to give up even his lectures in 1906 and everybody felt that the end was nigh. On Passion Sunday, the 5th April 1908, he preached with his usual vigour at the Church of the Sacred Heart, Dharmatallah; the excessive summer heat began to tell on him and on medical advice he had to leave for Darjeeling. He spent his last happy days with the boys of St. Joseph's school. He liked noise, he said, and the merry laughter of boys was, he thought, the best tonic for a jaded liver. On 6th May a sudden stroke of paralysis made his condition grave and he breathed his last on 10th May, 1908.

VI

If for nothing else, Father Lafont shall be ever remenbered as the teacher of Sir J. C. Bose. The brilliant teacher

moulded the aspirations of this young pupil for the starry heights of scientific attainment. When Sir Jagadis had made his important discovery on 'telegraphy without wires', Father Lafont publicly demonstrated the experiments and paid his student a well-deserved tribute (19th Sept. 1897). The Father mentioned that Bose's discovery preceded that of Marconi; in contrast to the latter, Bose did not take any patent, as he thought that result of any scientific discovery should be a public property. "Prof. Bose, whose modesty was on a par with his merit, had requested his old master not to mention all these, but Father Lafont was determined that justice should be done to whom justice was due."

Besides Sir J. C. Bose, many other students were influenced by Rev. Father Lafont's teachings and adopted science as the main guiding principle in their lives. To name a few, the instances of Richard Bradley, irrigation engineer at Roorkee, Dr. Arthur Younan (later trained at Edinburgh), a famous research worker on the vitreous humour of the eye and a renowned medical practitioner, Mr. E. R. Deefholts, electrical engineer (an expert in electrification of tramways), Mr. Devendra Nath Mullick, a physicist, Mr. Hariprasanna Chatterji (Swami Vijnanananda of Ramakrishna Order), an engineer, Mr. P. N. Bose, a famous geologist etc. may be cited.

Father Lafont exercised his noble influence not only upon his students but also on the contemporary intellectuals and royal dignitaries. Dr. Mahendra Lal Sircar, Justice Gurudas Banerji, Sir Ashutosh Mukherji, Sourindra Mohan and Jatindra Mohan Tagore, Moulvee Abdul Lateef Khan, Babu Rajendralal Mitra and many other intellectuals were deeply impressed by what Father Lafont preached and did. The then Nawab of Murshidabad, Maharajah of Gwalior, Maharani Swarnamoyee as well as many chief justices of High Court and Lt. Governors considered Father Lafont "as one of their best friends"; the above statements can be proved by a host

of well-connected references. He was able, amid the jarring discord of public life, to direct the mind of statesmen and administrators to those great moral issues of justice and of right on which the happiness and contentment of the people depend. Sir Ashutosh remarked, that Father Lafont had "a very deep sympathy with the aspirations of educated Indians". This remark is extremely significant when viewed in the context of nationalistic agitations in the beginning of this century. One cannot fail to note without amazement the connection of the great Father with a huge number of organisations and associations. Mahomedan literary society, Burrabazar Family Literary Society, various women educational organisations, * Calcutta Homeopath Society, Society for prevention of cruelty to Animals etc. enrolled Father Lafont as their active patron or member. Indian Association for cultivation of science, the Calcutta University and Asiatic Society of Bengal however occupied the greater part of his attention.

The tremendous impact, he made on the contemporary public opinion can be best judged from the honours he received during his life time. A man of God, as he was, he valued his decorations viz., 'Companion of the Indian Empire' (1880), 'Officier d'Academic de France' (1896), 'Knight of the order of Leopold' (1898), 'Doctor of Science' in Calcutta University (1908), only because those were beneficial to the cause of Bengal Mission ("all these for Chotanagpur" as he used to say)[1]; his heart, however, pined for divine rewards alone.

* Father Lafont used to deliver lectures on Science at Victoria Institution (founded by Keshub Chandra Sen), Loretto Convent etc. Sm. Indira Debi Chaudhurani had been one of the Father's pupils at Loretto Convent.

VII

Father Lafont was a man of Christ; he advocated for the modern science, only because he thought that neither Christianity was anti-scientific nor science anti-religious. After coming to India, he pursued his theological studies and began preachings on various topics of religion and Christian faith. His sermons against Freemasonry (a cult of secrecy and anti-christianity) in 1875, Triduum speches in 1888, charity sermons in 1899, speech on Saint Francis Xavier in 1901 and numerous 'Retreat'—sermons attracted catholics and non-catholics alike. He preached what he himself cultivated love, charity, readiness to help others * and above all religious faith. He stressed that the ideal way of exercising one's faith was "never to be ashamed of it and never to sacrifice it for worldly advantages". In the age of Ramakrishna-Vivekananda, he nobly and significantly represented in India all that was best in Catholic faith. If he wanted anything in his mortal life it was an eternity of divine bliss. At his death bed, he exclaimed, "Spare me human honour! I am thirsting for eternity".

VIII

To evaluate the profound influence exercised by Father Lafont on Indian renaissance, a critical assessment must be made of his scientific achievements and belief.

As justice Gurudas Banerji said, "Father Lafont's mission has been to popularise the study of science in this country". (With a rare power of exposition which recalled 'la maniere de Tyndall' he succeeded in that noble mission.) "Through the dissemination of Western culture, there has been a reaction in favour of the study of science ; and with this salutary reaction the name of the Rev. Father Lafont

* Rev. Father A. Briot said that one of the characteristics of the great Father was that "he was always ready to help."

must ever be most gratefully associated". Besides delivering popular lectures, he contributed largely towards the foundation of the Science Association, a tree which bore the fruits of Raman & Krishnan, and this, as the great Father himself considered, was the "best thing that he had done in India". It must be remembered, that when he first came in India in 1865, there was no laboratory worthy of the name; his missionary work in science was started when it was so badly needed in the country.

Speaking of the current belief that Father Lafont had been a mere popular lecturer, Sir Ashutosh Mukherji said, "No greater injustice could have been done to him. His knowledge of principles of science was as deep and as sound as that of any other scientist". The high proficiency which he attained in the study of Physical Science gives evidence that had he remained in Europe, he would have won a very conspicuous place in the world of Science. He however devoted himself to the cause of Bengal Mission, as "the needs of Bengal were many". The internationally-reputed British journal, 'Nature' regretted Father Lafont's death and remarked (May 14, 1908): "The influence of Father Lafont is to be found in many of the science courses of study at Calcutta University. His name will be long kept in mind as that of one of the pioneers of scientific education in Bengal; his death is a great loss, especially at this time when strenuous efforts are being made to put education in Bengal on a satisfactory basis".

Historians of scientific renaissance in India would do well to go through the various speeches and writings of Father Lafont in which he expressed his scientific belief and profound religious faith (the latter did not contradict but complemented the former).

His pursuits in the meteorological and astronomical sciences were nourished by a deep scientific philosophy which

was a dogma of experiment, observation and unbiased inference. He wrote a series of articles on 'Cyclone', 'Spectroscope' etc. In Indo-European Correspondence (Indo), he remarked, "Every accurate observation of natural facts is precious on account of the *possible* conclusions to which it may subsequently lead, although at the time it is recorded, it may seem of little use". He believed in facts but not in unfounded and dogmatic hypotheses. As he clearly explained in a communication to 'Indo' in October 16, 1869, "idle hypothesis led alchemists nowhere". In one of the early lectures, he said, "I belong to a religion commonly, though erroneously regarded as antagonistic to science. Well gentlemen, I declare to you, though a Catholic and Priest, I hail with delight and pursue with love any advance of true science, the only thing that frightens me being the pretended discoveries of men who are not satisfied with facts, but put in their stead, and erect into scientific dogmas, the ill-digested lucubrations of their imagination". According to him, an ideal scientific mind should be sufficiently liberal to accept and reconcile new facts. Six months before his death, when atomic science was only in its infancy, he gave the warning, "Let us beware of accepting all theories and mere working hypotheses as absolute truths. . . . . The discoveries about radium and other radiant substances must make us very cautious in assuming that we are already in possession of a final certainty about the constitution of matter and the forces of Nature in general. It is a great thing to learn how to say, "I do not know" instead of pretending rashly that we know all about everything".

There have been unconfirmed views (rather, rash pretension) that modern science has destroyed the claims of religion and secondly, that the nineteenth century religious revivalism has acted in Bengal in a direction opposite to the current of scientific renaissance. In fact, modern exponents of scien-

tific philosophy consider that science of to-day can neither prove nor disprove the claims of religion. Besides, as it has been rightly remarked by Dr. Bertram C. A. Windle, "The paths of science are not untreadable by the religious man, and as he walks in them, he will find in front of him the footprints of many who upheld the banner of religion as they did that of science". As regards the second part of the 'rash pretension', the views on science held and expressed by the monks of Ramakrishna Order * and the Jesuit Fathers in India should suffice to dispel the illusion.

The utterances of Rev. Father Lafont make it abundantly clear that his religious faith and scientific belief were harmonised in him into one concrete philosophy of Life: philosophy of God and 'God's positive works'. Rev. Father E. O'Neill, the successor of Father Lafont as Rector of St. Xavier's college, brought out this trait of Father Lafont's character very explicitly: "Many of us will remember how at the close of an interesting lecture, he would in accents of profound veneration, raise the thoughts of an enraptured audience to a feeling of thankfulness to the God of all truth who deigns to lift the veil of Nature's mysteries to give man a glimpse into the secrets of His own universe. On this point, he was uncompromising. Truth, he often asserted with that depth of conviction so characteristic of him, cannot be opposed to truth". His religious faith, love and sympathy to all, and many other Christian virtues, coupled with profound belief in science gave him an unique personality, which could not but indelibly impress itself on the emerging new India.

* Swami Saradananda and Vijñanananda were students of St. Xavier's College and in Father Lafont's science classes.

IX

The steady and useful educational work of St. Xavier's College had elicited the praises of the Bengali press even when the College was in its early teens. Following the examples of Father Lafont, the teachers of the College further contributed to the cause of education and science in this province.

Father Alphonse de Penaranda, one of the pioneers of Astronomical Science in India was an able colleague of Father Lafont; in his lectures delivered at the Science Association (1888) he regretted that a course on Astronomical Science had not been included in the University syllabus. He devoted his life to St. Xavier's College and to his favourite pursuit of astronomy, "which excited in him a kind of religious enthusiasm" ; his serene personality deeply influenced poet Rabindranath Tagore, who had been one of his students.

Father Lafont before his death, had not only left behind him in the college, the science laboratories "better equipped than any other in India" (Nature', 14. 5. 1908) but also several junior colleagues who were already well-received in the scientific society of Bengal*.

Father Lafont set an unique tradition in the domain of scientific research and education. Most people remember him as merely the teacher of Jagadis Chandra. However, his role on the stage of Indian science has been shown to be much more extensive and impressive. Modern India must recall his pioneering contribution towards science in the country with a spirit of reverence and gratitude.

* On February 14, 1908, Father A. Briot, along with Father Lafont, received Lord Minto, the then Viceroy, in the Astronomical Observatory

On Sept. 24, 1908, Father P. Van Neste was elected, along with Acharyya P. C. Ray, R. S. Trivedi, Dr. Watson etc., a member of the Executive Committee of 'Chemical Club' which served as a 'common platform on which scientists of all countries could meet'.

The author has been fortunate in having the opportunity of studying at the feet of these two great Jesuit teachers.

PIONEER SCIENTISTS IN MODERN INDIA

Throughout the nineteenth century, India continued to accept and assimilate occidental thoughts on science and education. The colleges and universities, established across the length and breadth of the country, produced a powerful intelligentsia, and this in its turn further unfolded a remarkable educational renaissance.

Indians grew more conscious of the likely impact of modern science on the individual and national life. However, inspite of the educational growth, there was very little scientific research done till the very end of the nineteenth century. This is hardly surprising, since the Britishers were always half-hearted in spreading scientific education in this country. Some of them were distinctly orientalist in their outlook; and quite a few considered that a knowledge of the three R's should be enough for the Indians.

Professor Ramchandra of Delhi was perhaps the first Indian to gain some recognition as a man of science in the 19th century. Born at Panipet in the year 1821, he served as a lecturer in Mathematics in Delhi (before the mutiny) and later at Roorkee ; his treatise on the problem of 'maxima' and 'minima' was published in the year 1850. Dr. Aghore Nath Chatterjee (father of the illustrious national leader Mrs. Sarojini Naidu) was the first Indian chemist to obtain D.Sc. degree in Chemistry (Edinburgh University, 1883). He pointed out certain errors in the book on 'Stereochemistry' written by the famous Dutch chemist, Prof. J. H. Vant Hoff. Professor Vant Hoff acknowledged his debt to Dr. Chatterji in the second edition of the book. Unfortunately, this brilliant Indian chemist, finding no suitable research facility existing in India, drifted towards an administrative career.

Similarly, Sir Ashutosh Mukherji, who began his career as an outstanding mathematician, eventually took up law and later education as his career. Ashutosh contributed quite a few original papers during the last decade of the nineteenth century on the following topics: Monge's differential equations, integral of Poisson, hydrodynamics, application of elliptic functions to problems of mean values etc. Dr. Ganesh Prasad, an eminent mathematician of our time has aptly remarked: "After Bhaskara, he (Sir Ashutosh) was the first Indian to enter into the field of mathematical research as distinguished from astronomical research, and did much which was truly original". Fortunately for our country, Ashutosh kept his passion for science aflame, and as the Vice-chancellor of the Calcutta University, organised post-graduate teaching and research in science for the first time in our country.

Inspite of all the pioneering efforts of Rammohun, Mahendralal, Lafont and Ashutosh, the roots of modern science could not have been firmly established in the Indian soil, without the supreme dedication of the researchers like Acharyya Jagadis Chandra Bose, Acharyya Prafulla Chandra Ray, Sir C. V. Raman etc. Prof. N. R. Dhar, a famous Indian chemist has fittingly remarked: "The dark age in mediaeval Europe lasted for 300 years, whilst in India, it persisted for over 1200 years i.e. from 700 to 1890 A.D. when Acharyya Jagadis Chandra Bose and Acharyya Prafulla Chandra Ray started experimental science in Calcutta."

II

Born at Mymensingh, East Bengal (now in East Pakistan) in 1858, Acharyya Jagadis Chandra Bose was destined to be a poet amongst scientists, a bridge-maker between the inanimate and the animate world. Father Lafont of St. Xavier's College, Calcutta, instilled in him a love for experimental physical science, and this was further nurtured under

the influence of Lord Raleigh, the famous British physicist. Yet, it is significant to note that Bose maintained a life-long admiration for the living objects. As a matter of fact, he started learning medicine in England before switching over to physics; kept close contact with Prof. Vines, the famous botanist; and during the later portion of his scientific career, diverted his attention from Physics to Physiology.

After obtaining Natural Science Tripos of Cambridge University and B.Sc. of London University, Bose returned to India in 1885, and accepted a teaching assignment in the Presidency College, Calcutta. The pay-scale offered to him was humiliatingly low and the research facilities were completely lacking. However, inspite of this (and perhaps because of this), he was determined to struggle for scientific achievement. He had little time to complain of his environment. Much later he wrote: "It is the habit of weakness to throw blame on others, on the university, on government, on unfavourable circumstances in general. It is not for a man to complain of circumstances, but bravely aceept them, confront them and dominate them."

Scientific research on electric waves was initiated by Bose in the early nineties of the last century. The famous scientist, Clarke Maxwell had suggested that light waves are of electromagnetic nature. This was verified by Hertz in 1880. The shortest electromagnetic wave obtained by Hertz was of wavelength as large as 5 metres. Marconi, Lodge etc. used electric waves of larger wavelengths. Contrasted to this, Bose produced extremely short waves (5 millimetre wavelength). In May 1895, he published his first paper: "On the polarisation of the electric ray" in the journal of the Asiatic Society of Bengal. A paper on the determination of the indices of electric refraction was submitted to the Royal Society of London through Lord Raleigh. Bose established the remarkable simi-

larity between the electrical and the optical beams, both being amenable to reflection, refraction and polarisation. He termed the electric waves as "broken glimpses of invisible light". A special crystal 'nemalite' was discovered which was found to polarise electric waves just as a light-beam is polarised by tourmaline.

Against the advice of his well-wishers, Bose made his discoveries public and refused to claim any patent. Recently, the centimeter radio-waves investigated by Jagadis are finding commercial application in Radar, Television etc. As early as 1895, Bose demonstrated the possibility of transmission of these waves to a distance. During a popular lecture in Calcutta Town Hall, he transmitted waves through a solid wall, "displacing a heavy weight, ringing a bell and exploding a mine, placed in a closed room."

Bose brought considerable improvement over Hertz's detector of electric waves. He was the first to use a semiconductor crystal like galena as a self recovering detector of electric rays (1901). Sister Nivedita and Mrs. Ole Bull of the Ramakrishna Mission were his admirers; they took patents (for the above usage) on his behalf in U. K. and U. S. A. However Bose never used his rights and allowed the patents to lapse. This supreme self-denial was often misunderstood as "unpractical quixotism". However, he was consciously following the noble example of the Indian sages who distributed knowledge—always free of cost.

Bose's pioneering research activities and lecture tours in U. K. and the continent brought not only unprecedented fame to himself but also an era of glory to his motherland (this has been beautifully narrated in several letters written by Tagore and Vivekananda). During 1899-1904, Bose pointed out that there exists an intimate parallelism between the response of the inorganic matter and of the living substances. He found that the curve of the fatigue of an instrument closely resembled

the fatigue-curve of an animal tissue. His explanations were however much debated in England and Europe.

The numerous instances of similitude between the responses of the living and the inert encouraged Bose to take up the study of life sciences, and plant physiology in particular. He invented 'crescograph' in which the imperceptibly slow growth of plant could be magnified several million-fold and accurately recorded. He further substantiated his findings by actual demonstrations before the members of the British Royal Society (1914). "His 'resonant recorder' registered the speed of transmission of excitatory impulse; the 'oscillating recorder' traced the throbbing pulsations of the telegraph plant and finally the 'death-recorder' indicated the death-throes of the plant". Even Sir William Crookes, who had been skeptical about Bose's scientific claims, yielded in accepting the merit of new discoveries. The first book of Jagadis Chandra recounting the results of his investigations was entitled "Response in the living and the non-living". It was hailed as a masterpiece by the entire scientific world.

Bose's scientific career was eventually crowned with glory when he was offered the knighthood and elected as a Fellow of the Royal Society (1920). Probably the happiest moment of his life came on his 59th birthday (November 30, 1917) when he inaugurated his own research institute. This research institute according to him was "not merely a laboratory but a temple". As a matter of fact, the institute is called 'Basu Vijnan Mandir'—a temple of science. Directed by him and later by his physicist nephew, Dr. D. M. Bose, this institute has remained an important centre of research in physical and biological sciences.

Bose passed away in 1937. Eight years later, a biographical note on him appeared in the Encyclopaedia Britannica. It mentioned that his biophysical research was "so much in advance of his time that its precise evaluation was not possible".

III

The 'Father of Indian Chemistry', Acharyya Prafulla Chandra Ray was three years younger than Bose; he was born on August 2, 1861, also in East Bengal. He completed his initial education in Calcutta and then proceeded to U. K. in 1882 for higher studies in Chemistry. Ray received his B.Sc. in 1885 and D. Sc. in 1888 from Edinburgh; he became acquainted with the famous chemists such as Marshall, Crum Brown etc. at Edinburgh.

On return to India, Ray followed the footsteps of Bose in joining the Presidency College, where research facilities scarcely existed. The authorities believed that the institutions were mainly for teaching and that faculty research would involve *wastage* of time and money. Some British science-educated teachers however felt otherwise. Sir Alexander Pedler, the then Principal of the College was doing some research on Cobra venom; he established that the active principle is basic in nature and forms well-defined platinichloride and aurichloride. Sir Pedler gave ample encouragement to Ray and helped him to acquire useful equipments and chemicals. Chandra Bhusan Bhaduri, Pedler's lecture assistant, also helped Ray considerably in performing scientific experiments.

In 1894, Ray started investigations on minerals to hunt for the missing elements in the periodic table; no worthwhile result was however obtained. The discovery of mercurous nitrite was a turning point in Ray's career. Action of dilute nitric acid on mercury gave "a yellow crystalline deposit" which was established to be the above compound. This finding was reported to the Journal of Asiatic Society (1896). The famous British journal 'Nature' commented : "The Journal of Asiatic Society can scarcely be said to have a place in our chemical libraries; the current number however contains a paper by Dr. P. C. Ray of the Presidency College,

Calcutta...." Following this publication, an unbroken series of papers on the nitrites was published in the Journal of Chemical Society, London. Ray and his pupil, N. R. Dhar published a paper on the vapour density of ammonium nitrite indicating that this compound hitherto believed to be unstable, could be vapourised and its vapour-density measured. When this paper was presented before the London Chemical Society, Ramsay and Veley warmly congratulated the authors. Professor Armstrong commented to Ray: "The way you have made yourself a master of 'nitrites' is very interesting".

By 1902, Ray had completed his monumental work on the "History of Hindu Chemistry" which covered the period since the ancient ages upto the sixteenth century. Pandit Navakanta Kavibhusan had considerably helped Ray by deciphering valuable Sanskrit texts. Congratulations were showered on Ray by Berthelot in his 15-page review in the Journal des Savants (January 1903). Arrhenius and many others accepted the pioneering role of Indian chemists in the ancient ages.

Ray not only established the ancient glory of Indian science but also inspired the Indian youth in undertaking new ventures in science and technology. Under his able leadership, a group of youngmen established 'The Bengal Chemical and Pharmaceutical Works' on April 12, 1901. Many other industrial concerns like 'The Calcutta Pottery Works', 'Bengal Enamel Works' were floated, largely with Ray's inspiration and technical guidance. It may be recalled that towards the end of the nineteenth century, there was a big controversy involving the question of priority of scientific education and research of fundamental nature vis-a-vis technical education and technological growth of the country— Mahendralal and his followers arguing for the former and the members of the 'Indian league' particularly Krishnamohan and Sisir Kumar being in favour of the latter. The controversy

was kept alive even in the first two decades of the twentieth century, when the leaders of the 'national education' movement urged for boycott of universities and preferred technical education over liberal scientific education. Ray instead of entering into the controversy, resolved this; through his deeds, he preached that scientific research and industrial progress are equally needed in the national development and should go hand in hand.

Ray's school of Indian chemists has been probably his biggest contribution to the Indian science. He frequently referred to his pupils and 'grand-pupils'. Referring to Ray's lecture in London delivered on 10th January, 1916, 'Nature' commented in its March 23 issue :

"The lecture consists of a brief resume of original chemical research as carried out in Bengal in the last twenty years, and as an appendix a list of 126 papers. Some of these are of very considerable value and interest, and indicate enthusiastic work on the part of this *newly created school, which is mainly due to the example and work of Professor Ray himself*" (italics are mine).

Ray trained literally hundreds of students in the Presidency College and later in the newly established Chemistry department of the University College of Science. His students in their turn adopted the profession of chemical research and spread out all over the country. A few examples may be given to illustrate this point.

N. R. Dhar after completing his pioneering work on ammonium nitrite under Ray, proliferated his research activities at Allahabad. Dr. B. B. Dey initiated a school of organic and biochemical research in Madras; some of the best organic chemists of our times were Dey's students. Dr. H. K. Sen proved to be an outstanding applied chemist particularly in the field of high pressure reactions and glass technology. The works on sulphur chlorides by Naik, a Bombay University

graduate, under Ray; on conductivity of strong electrolytes, photochemistry and catalytic reactions by J. C. Ghosh on electrical double layer theory by J. N. Mukherji etc. brought fame to Indian science and to Ray's School of Chemistry in particular. Dr. S. S. Bhatnagar, who did outstanding work on Magnetochemistry had studied at Lahore under Prof A. C. Ghosh (who in turn was Ray's student); he used to say that although he was not a direct pupil of Ray, he was his 'grand-pupil'.

We should also mention here, a few names of chemists who did not belong to Ray's school but nevertheless helped the profession of chemical research in India. Prof. E. R. Watson developed his independent school of applied chemical research while he was at the Shibpur Engineering College and then at Dacca and later at the Harcourt Butler Technological Institute, Kanpur. Dr. M. W. Travers, the first Director of the Indian Institute of Science, Bangalore (established by Sir Jamshedji Tata in 1906) was a well-known chemist, having collaborated with Sir William Ramsay in the discovery of Neon, Krypton and Xenon. Later Profs. Fowler (biochemist) and Sudborough (organic chemist) were also associated with this institute and helped in creating a climate of chemical research in South India. Nevertheless, Ray's influence was the most decisive factor in the growth of chemical research in our country.

IV

Mahendralal and Ashutosh had prepared the ground for scientific research in India; Bose and Ray were the early toilers; to complete the metaphor, it could be said that Raman, Krishnan, Saha and Satyen Bose reaped the harvest.

Born on Nov. 7, 1888, Sir C. V. Raman had his early science training in Madras and came to Calcutta in 1908 as a government officer and with a burning but hitherto impotent desire for scientific research. It was Ashutosh who helped him towards his evening research activity in the Indian Asso-

ciation for Cultivation of Science at Bowbazar Street and eventually selected him as the Palit Professor of Physics of the Calcutta University in 1917.

Raman conducted pioneering research in musical acoustics particularly on the Tamboura, the well-known Indian musical instrument. This work made him famous; he was invited by the German Physical Society to contribute an article on the theory of musical instruments for their Encyclopaedia of contemporary Physics (Handbuch der Physik).

The renowned physicist, Smekal had predicted on the basis of the particular nature of light that when a light photon meets a molecule like benzene, it may emerge with some loss or gain of energy, this energy being imparted to or abstracted from the molecule. Raman and his co-worker, K. S. Krishnan observed the scattering effect of monochromatic light undergoing change in wavelength, known as Raman Scattering effect; for this remarkable discovery, Raman was awarded the Nobel prize in Physics in the year 1928. The discovery not only proved Smekal's hypothesis but also laid the basis of understanding of the energy levels and structure of atoms and molecules. Since 1933, Sir C. V. Raman has been working at Bangalore on internal architecture of diamond crystal, theory of colour perception and several other fundamental problems.

Professor K. S. Krishnan, after working under Raman, pursued independent investigations at Dacca University (1928-33), then back at Calcutta University (1933-1947) and afterwards at the National Physical Laboratory, Delhi till his death in 1961. His research interest was broad and covered diverse topics such as magnetic properties of crystals, energy distribution of electrons in graphite crystals, metal physics, light scattering, thermionics etc. He was supremely gifted as an experimentalist.

Professor Meghnad Saha and Prof. Satyen Bose received

early inspiration from their teachers, Acharyya Jagadis and Acharyya Prafulla Chandra. Saha was an indefatigable worker. His epoch-making equation relating to stellar spectra has been aptly termed as "one of India's most precious gifts to world science". Saha postulated that at very high stellar temperatures (of the order of several thousand degrees centigrade), constituent atoms lose orbital electrons which become free; the process is called 'ionisation'. The spectroscopic evidence of this phenomenon has been obtained. Saha's equation, modified later by Fowler, Milne etc. embodies his original quantitative approach correlating the degree of ionisation with the temperature and pressure in a given stellar system. Later, Saha founded the Institute of Nuclear Physics (now named after him) in Calcutta and initiated a very productive research school on the subject. He was the chief architect of river planning in India. His acute concern for the socio-economic upliftment of the country led him to politics and lasted till his death in 1956.

Prof. Satyen Bose, happily still with us, has differed from Saha in temperamental approach towards life in general but not in his supreme thirst for scientific research. He has always been deeply interested in the fundamental problems of mathematical physics. His name is inseparably linked with Albert Einstein, as every science student ought to know; the famous Bose-Einstein statistics is a distinct improvement over the earlier statistics in the names of Maxwell and Boltzman which, as Bose pointed out is applicable to the gaseous molecules but not to the individual photons. Bose's contribution to unified field theory is also well-known. The modern scientists have expressed their appreciation and indebtedness to Bose by classifying sub-atomic particles into two categories: 'fermions' after Fermi and 'bosons' named after Satyen Bose. Bose has been well known for his philosophical temperament, broad interest in national problems

and education and particularly for his championing the cause of popularisation and teaching of science in mother tongue.

V

The names of Ramanujam, Bhabha and Chandrasekhar do not properly fit in the lineage of tradition set by Mahendralal, Raman, Bose and Ray; however, this article would be incomplete if their achievements are not mentioned. Srinivasa Ramanujam, a child prodigy was a pure mathematician of the highest order. Born and brought up at Kumbakonam, Madras, he showed startling promise as a mathematician even in his childhood. Reports about him drew the attention of Professor G. H. Hardy of the Cambridge University, who brought him to England, to coach him as well as to "collaborate with him on something like equal terms". Prior to his premature death in 1920 (when he was barely 33 years old), Ramanujam had contributed original research papers on the theory of numbers, Riemann's Zeta function, mock theta function, modular equations, theories of continued fractions, elliptic function etc.

Homi Jehangir Bhabha has been well known as the first Director of the Atomic Energy Establishment in India (now named after him). His untimely and tragic death (by air crash on 24th January, 1966) has been truly a national loss. His chief scientific contribution has been the 'cascade' theory of cosmic-ray showers, relating to the soft component of secondary cosmic rays. Bhabha worked out the detailed mathematical aspects of his theory. He also developed the vector theory of the meson, a sub-atomic particle, as early as 1938. Bhabha has undoubtedly been one of the chief architects of research in fundamental physics in India ; the establishment and growth of the Tata Institute of Fundamental Physics and the Bhabha Atomic Research Centre bear eloquent testimony to his scientific skill and prowess. The

recognition of his leadership in the field of nuclear research was evident when he was elected to preside over the international conference on the peaceful use of atomic energy held at Geneva in 1955.

Subrahmanyan Chandrasekhar though born and educated in India till 1930, owes all his scientific achievement in astrophysics to the West where he has been working for over three decades (at Cambridge, U.K. and now at Chicago, U.S.A.). He is now an American citizen and recently received the highest national award on scientific achievement from the U.S. President. Nevertheless, it is interesting to note that he is a nephew of Sir C. V. Raman from whom he received an early inspiration for a scientific career. Chandrasekhar's vast output of scientific work relates to : course of stellar and galactic flames, properties of 'plasma' (ionised gas) under high temperature, pressure and magnetic field, effects of gravitation, electro-magnetism and turbulence on stellar and galactic matters etc. Although, Chandrasekhar has been working in the U.S.A. since 1936, he remained an Indian citizen till 1953, when he accepted the American citizenship. He decided to settle abroad so that he could serve science in the best manner.*

Prof. D. S. Kothari, in a sense Chandrasekhar's counterpart, was Saha's student at Allahabad. He received higher education at Cambridge and pursued scientific research on astrophysics in India. Kothari laid the foundation of the 'theory of pressure ionisation', according to which very high pressure unaided by thermal factors could ionise materials. He deduced that such degenerate matter existing under high pressure and low temperature condition

* Similarly, India-born Dr. Har Govind Khorana, who has been awarded the 1968 Nobel prize in Medicine for his outstanding contribution in the field of Genetics, has settled in U.S.A. and is thus lost to Indian science.

(as in white dwarf stars) can not form an object having *volume* greater than a critical limit (size of the Jupiter planet). This postulate reminds one of Chandrasekhar's prediction as regards the critical maximum *mass* that a white dwarf star may attain.

In the capacity of the Scientific Adviser to the Ministry of Defence, Kothari initiated useful research projects on behaviour of metals under explosion pressure and also on ballistics, electronics etc. As the current Chairman of the University Grants Commission, he is trying to rejuvenate science education in the Indian universities.

In this article of limited scope, it is neither possible nor necessary to mention all other scientists like P. C. Mahalanobis, the statistician, Birbal Sahni, the palaebotanist, J.B.S. Haldane, the British born biologist etc.—whose scientific works in India have produced a congenial atmosphere of research for budding Indian scientists. During the last eighty years, numerous researchers have been able to put our country on the scientific map of the world.

Nevertheless, as we shall see later, the current trends of scientific activity in India leave much more to be desired. There can not be any room for complacency. With science departments of 68 universities, over 200 technical colleges, 50 national laboratories, numerous research organisations sustained by public and private funds, and above all with the brilliant examples of the earlier Indian researchers to emulate, it is hoped, however, that the Indian youth would feel sufficiently encouraged to adopt scientific career and to serve the nation by contributing towards the progress of scientific knowledge and technological achievement.

RELIGION AND SCIENCE IN THE INDIAN CONTEXT

Herbert Spencer once remarked, "Of all antagonism of belief, the oldest, the widest, the most profound, and the most important is that between religion and science". Perhaps the episode of Galileo and the famous 'inquisition' was in Spencer's mind. However, is this comment to be accepted as valid in the perspective of the Indian history also ?

Since the Vedic ages, the Indians developed the faculty of mental concentration and contemplation, supreme thirst for 'eternal life' and above all, a spirit of enquiry regarding the mystery of life, the universe and its supreme creator. Certainly, not the entire population in the ancient, mediaeval and modern India has subscribed towards this other-worldly philosophical view-point. Many thinkers like Charvaka have preached atheism and what is known to-day as existentialism. Yet, seers like Buddha, Shankara, Ramanujam, Nanaka, Chaitanya, Meera Bai and recently Ramakrishna and Vivekananda have proclaimed the existence of a divine force, which is the true basis of religion. Their claims of having obtained mystical communion with the supreme creator, and their remarkably noble and selfless characters inspired millions to embrace religion as the principal path in life. Thus in India, religion has been fittingly defined as the path of realisation—realisation of divinity within oneself and in the universe.

Religious thinking in India has deeply influenced the cultural pattern in this country. Almost the entire edifice of Indian culture with pillars of musical, literary and artistic traditions rest on the solid foundation of religious and

metaphysical ideas. The remarkable continuity of cultural pattern across the ages, indicates that the Indian way of life must have drawn its enduring vitality from the deep well of ethical and religious concepts.

Nevertheless, it is a paradox as pointed out by some historians, that inspite of the noble guiding force, the dynamic nature of Indian civilisation has been lost, the country has been repeatedly invaded, plundered and subjugated and the living standard of the inhabitants often followed a persistently downhill trend. The decay, if not the downfall of the Indian civilisation may have been due to the replacement of the rational spirit of enquiry (without which growth of scientific culture is never ensured), by a blind idolatry of the ancient ideals.

At this point, we are confronted with several vital questions.

Firstly, has the material backwardness of the Indian nation been essentially due to the doctrine of 'other-worldliness' in Indian religion, or to some other factors ?

Secondly, are the religions in India, particularly Hinduism, opposed to the spirit of reason and logic, which is the essence of scientific culture ?

Thirdly and lastly, do religion and science in general, represent antagonistic and irreconcilable cultures, as suggested by Herbert Spencer ?

We may examine and seek answers to the three formulated questions, in succession. Satisfactory answers should also enable us to ascertain the possible role of religion in the future science-based society of our country.

II

In a previous article, the chronology as well as the probable reasons for decline of Indian science have been outlined. Up till the eighth century since the birth of Christ,

India was decidedly advanced in scientific achievement as well as in material prosperity. The role of religion in Indian society was also at its pinnacle of glory. Hinduism and Buddhism had been spread far and wide in the Asian continent. Influence of the religious leaders and the holy scriptures on the Indian life and thinking had been supreme. If the 'otherworldliness' of Indian religions has to be made the scape-goat for the subsequent decline of science and material prosperity in the country, how does one explain that for several centuries, India had excelled in religion as well as in science and material prosperity simultaneously ?

The nation which considered religion as essential in its fabric of culture, also promoted science, technology and overseas trade. Studies on the reigns of Chandragupta, Ashoka, Harshabardhana give ample support to the above statement. The religious leaders and their followers not only toured the length and breadth of India for the dissemination of their noble culture but also covered most of the Asian continent to instruct the people to lead noble and purposeful lives. Indian religious culture was dynamic, rational and without traces of negativism, fatalism and indifferent pessimism, which are usually implied in the derisive term 'otherworldliness'. Liberal education and science were taught and practised in the monasteries and religious centres of Nalanda, Varanasi, Taxila etc. These facts are perhaps inconvenient to the easy-going theorists who hold the Indian religious culture to be responsible for the decline of science in this country!

The multiplicity of socio-economic and political factors leading to the decline of science and material prosperity in India has been stressed in a previous article. Albiruni noted in the 11th century that Indians had become vainglorious about their earlier religious and scientific achievements and this was in contrast with the remarkable humility and thirst

for knowledge of their predecessors like Aryabhat and Varahamihira. The Indians became ignorantly boastful of their culture and considered that they had nothing to learn from any other nation. This kind of vainglory was common in mediaeval China also and it persists even today in modern India. Late Professor Meghnad Saha used to recall the following incident. When he was describing his recent scientific discoveries to a lawyer friend at Dacca (now in East Pakistan), the latter remarked : "O! all these topics are mentioned in the Vedas". This kind of ignorance and vainglory was one of the most important factors arresting the growth of Indian science after the ninth century. However, do we blame the religious scriptures for the foolish statements of those who refer to them without having read them. The Hindu scriptures have never claimed discovery of all the scientific laws; on the other hand, the Vedas recommend the spirit of enquiry and experimentation for the discovery of truth. If an individual claims that science is in possession of all truths, do we blame science or the ignorant individual ? Hindu religion can not be blamed for the pseudo-religious feelings of the Hindus—their vainglory and as we shall discuss now, their pessimism and fatalism, which are not sanctioned by the scriptures.

By the tenth or eleventh century, the Indians had lost contact with the external world, intellectually as well as physically. They were internally divided and subjected to repeated invasions. The invaders and the conquerors destroyed the seats of learning and thus caused irreparable damage to the Indian science. The Hindu society, already frozen by the caste structure and rendered impotent against the invaders, lost all facilities and interest for the pursuit of science. The Moslems, the new rulers of the country were unduly engaged in warfare and subjugating their enemies. They seldom cared either to promote the established traditions

of the Hindu science or to imbibe the newly emerging Moslem science from the Arabian countries and the Central Asia.

While the rulers and rebel kings were busy in internecine wars and in unnecessary pomp and festivity during the brief peace time recesses, the vast population of the country remained half-starved and gasping under the tyrannical yoke of the rulers. The people, mostly uneducated and helpless as they were, naturally turned towards pessimism and fatalism—a peculiar thought-product which originated from deep sentiments of despair and frustration.

Some of the 'intellectuals' of our time do not have the patience to examine the socio-economic genesis of the fatalistic and pessimistic trends in Indian thought. Nevertheless, they are blissfully satisfied with the conclusion that the Hindu theory of 'mayavada' is responsible for this fatalism. It would be amusing to find out how many of the ignorant and pessimistic Indian villagers who painfully resign by saying, "this world is maya or non-existent", and how many of the above mentioned 'intellectuals' have read the original texts of Shankaracharyya and other exponents of Indian mayavada. The Indian philosophers while pointing out the illusory nature of the world as we perceive it, were merely suggesting the existence of a much broader, truer and everlasting reality, not accessible to the uncultivated physical senses of ours. They never preached any doctrine of inaction on the basis of 'non-existence' of this world. Shankaracharyya was himself a tireless proponent of action. The Gita violently repudiates the concept of inaction which is qualified as irreligious and hypocritical. The duties of men and women in different walks of life have been clearly outlined and defined as inviolable in the ancient scriptures. The right of renunciation has been given only to the genuine seekers of truth and not to the idle and the hypocrite. Even if the fatalistic tendencies in our country are due in some measure to the misconception of the

scriptures (which is doubtful), are the scriptures to be censured? Should we blame Science for the evils accruing out of its misunderstanding and misuse?

III

'Religion' as a cultural parameter can be split into two components : one ideological-motivational and the other institutional-organisational.* While the first component represents the essence of religion, the second constitutes the external aspect which varies with location and time-scale in history. To judge a religion such as Hinduism, we should consider its essence instead of the institutional-organisational part, which has undergone tremendous variation since the Vedic ages, and demerits of which have been excessively harped upon by the antagonists of religion. For instance, the caste system in the ancient ages was based on occupation of an individual and not on ancestry. During the mediaeval period, the caste structure became rigid, forbidding the freedom of occupational choice and social interaction; this decidedly arrested the progress of our culture and material prosperity. However, the rigidity in caste structure has been, in the first place, an abuse of the original concept of division of labour and does not impair the bright image of the lofty philosophical ideals of Hinduism. Although there have been structural inadequacies in the Hindu society, it has been rightly pointed out by Sri Dube that the basic content and value system in Hinduism has progressive elements which could even encourage and stimulate economic growth.

It is undeniable that the economic prosperity of a nation depends largely on science, technology and efficient commerce. Hence, we may consider the second question formulated in the

* Vide "Cultural problems in the economic development of India" an article written by Sri S. C. Dube, published in the Proceedings of Symposium on 'Religion and Progress in Modern Asia' edited by R. N. Bellah, The Free Press New York, 1965.

beginning of this article, viz., whether the Indian religions, particularly Hinduism, oppose the scientific spirit of enquiry and experimentation and thus indirectly hinder material prosperity of the nation and its people. A close examination of the scriptures reveals that the answer is negative.

Realisation of the spiritual truths and not unquestioned and unverified belief in dogmas, has been accepted as the essence of Indian religion. The great mystics while narrating their spiritual experiences, forbade us to naively accept their words without verification. India has always upheld search and direct experience as the two touchstones of religion. The Indian spirit has always been against dogmatic belief and in consonance with what we may call the true scientific spirit of enquiry. Vedanta, the science of the inner self, exhorts us to question, examine and find the true nature of our 'self' and can not be considered by any stretch of imagination to be antagonistic to the philosophy of modern science.

Turning to the question of material prosperity, it must be stated that religion has almost nothing to do with it. Very often, a senseless question is asked : if our religion is so glorious, why it has failed to remove the poverty in the country. The best answer to this question has been provided by Swami Vivekananda in his lecture on "The science and philosophy of religion" :

"Many people ask 'What good can religion do? Can it take away the poverty of poor?' Supposing it can not; would that prove the untruth of religion? Suppose a baby stands up amongst you when you are trying to demonstrate an astronomical theorem and says : "Does it bring ginger-bread?" "No, it does not", you answer. "Then", says the baby, "it is useless". Babies judge the whole universe from their own standpoint, that of producing ginger-bread and so do the babies of the world".

On another occasion, when specifically asked as to why

religion has not improved Hindu economy, Swami Vivekananda gave a categorical reply: "Because that is not the sphere of any religion; no religion has ever advanced the material prosperity of a nation".

Thus, it can be safely asserted that the reasons for the chronic economic stagnation in India during the last few centuries do not lie in her genuine religious activities and sentiments which have never stood in the way of scientific progress and technological achievements. Some intellectuals may still argue that religious thinking has been a sort of distraction and thus indirectly hindered material achievements of the nation. To follow this logic, Jesus Christ's life and influence must be considered as extremely reactionary in the context of material prosperity of the mankind. Like religion, music and literature must also be censured for hindering scientific progress. Who knows, someday, poets like Kalidasa and Tagore may be severely criticised for having diverted the interests of people towards unnecessary aesthetics and thus rendering gross disservice against the spirit of scientific achievements in the human civilisation!

If a nation has failed to stimulate ecientific study and research amongst its people, only its indifference towards education and science, its internal weakness and the prevailing adverse socio-economic factors should be held as genuine reasons; it would be unfair to single out the religious life of its people as the proverbial scape-goat.

IV

Having examined the first two questions as regards any possible adverse influence of religion on Indian science and economic welfare of the country, we may analyse the third and the most fundamental problem: whether the inherent philosophies underlying the two cultures, religion and science are basically antagonistic and incompatible as Her-

bert Spencer suggested. The chronology of the 'dispute' between the two cultures is interesting to study and may be briefly narrated.

The controversy between the orthodox Christian church and the newly emerging scientific philosophers was admittedly acute during the mediaeval ages. The discoveries made by Darwin and Newton showed that many mythological and theological doctrines do not stand the scrutiny of observation and logic. Newtonian mechanics gave adequate explanations of a large number of earthly and astronomical phenomena; people started regarding that the new science had completely outmoded the old religion. The mathematical laws governing the motion of material objects were held to be supreme. Laplace felt courageous enough to affirm that "a sufficiently great mathematician, given the distribution of the particles in the primitive nebula, could predict the whole future history of the world". The atomistic viewpoint, principles of mechanics and the fundamental axiom of causality were considered adequate for explanation of *all* natural events. Intoxicated by the early successes of scientific endeavour, many people felt that religion was no longer a matter of interest for the intellectuals.

Early in this century, discovery has been made concerning the dual (wave-like and particulate) properties of light and electron; this imparted a rude blow to the idol-worshippers of Newtonian mechanics. At this point, religious revivalists claimed that science need not be considered as final, infallible and capable of explaining *all* events. Laws of statistical mechanics clearly postulated that while gross behaviours of subatomic particles in a particular environment are predictable, nothing could be said about the exact location and velocity of individual particles. This principle of 'uncertainty' or 'indeterminacy' tempted many persons including scientists of the stature of Eddington and

James Jeans to "rehabilitate the religious concept of free-will" in the name of inadequacy of science. This viewpoint was violently opposed by Bertrand Russell, Einstein and others (such as Prof. Meghnad Saha of our country). Russell's view point may be quoted at some length :

"In recent times, the bulk of eminent physicists and a number of eminent biologists have made pronouncements stating that recent advances in science have disproved the older materialism, and have tended to re-establish the truths of religion. The statements of the scientists have as a rule been somewhat tentative and indefinite, but the theologians have seized upon them, so that the general public has derived the impression that Physics confirms practically the whole of the Book of Genesis. I do not think that the moral to be drawn from modern science is at all what the general public has thus been led to suppose. In the first place, the men of science have not said nearly as much as they are thought to have said, and in the second place what they have said in the way of support for traditional religious beliefs has been said by them not in their cautious scientific capacity, but rather in their capacity of good citizens, anxious to defend virtue and property. . . . . . .

"Eddington deduces religion from the fact that atoms do not obey the laws of mathematics. Jeans deduces it from the fact that they do. Both these arguments have been accepted with equal enthusiasm by the theologians, who hold apparently, that the demand for consistency belongs to the cold reason and must not interfere with our deeper religious feelings".

("The Scientific outlook"—Bertrand Russell)

It has to be accepted, as Russell, Saha and others have argued, that the proposition of indeterminacy for an individual subatomic particle does not in any way disprove the basic causal principle on which Science rests. While deifi-

cation of the scientific discoveries and laws is unscientific, justification of religion should not be sought in the inadequacies of the scientific laws (as done by Eddington in the West and religious revivalists like Dilip Roy of our country).

Although, physical laws are getting more and more refined and it is believed that most of the facts in the inanimate world may be interpreted through sophisticated knowledge of mathematics and physical sciences, it is doubtful if the mechanistic causal principles could completely explain the phenomenon of 'life'—its creation and function. Non-biologists like Bertrand Russell have always ignored the problem of 'life'. Russell has stated with a characteristic tone of neglect :

"In passing from physics to biology, one is conscious of a transition from the cosmic to the parochial......From a cosmic point of view, life is a very unimportant phenomenon".

Nevertheless, the controversy between science and religion centres precisely around the mystery of life. Let us illustrate this point by framing a question. Can all the actions of a living body be explained in terms of its constituent atoms and molecules or at least a part of its actions is attributable to the free will of the living body? If the concept of free will of living objects is accepted, does it not go against the principle of causality from a materialistic point of view? It is amusing to imagine that some modern biophysicist may have the 'free will' to try to show that the actions of a living object originate completely from the energetics of atoms and molecules in the nervous system and are not due to its free will !

In a more serious tone, Pierre Teilhard de Chardin has remarked in his 'The phenomenon of Man' : "The apparent restriction of the phenomenon of consciousness to the higher forms of life has long served science as an excuse for elimi-

nating it from its models of the universe. A queer function, an aberrant function, an epiphenomenon — thought was classed under one or other of these heads in order to get rid of it. But what would have happened to modern physics if radium had been classified as an 'abnormal substance' without further ado?"

John Langdon—Davies advances similar argument in his book "Man : the known and the unknown" :

"When people fail to understand the nature of scientific law, they may easily be deceived into denying a few fact because it does not fit into some law which has hitherto been a law simply because all previous facts *did* fit into it. There are many facts about human nature which are still denied because they are thought to destroy some scientific law."

"There are scientists, for example, who deny that telepathy can exist. This is how they argue : information can not pass from one person to another without some sort of energy-exchange ; thus, if we tell somebody something, energy has to be used to cause sound waves and neural discharges. In telepathy, there is no place for energy exchange as physics knows it, therefore telepathy does not exist and anyone who says it does is either self-deceived or a plain liar. That is an example of arguing from law to fact, as if scientific law could annihilate a single fact. It is not a scientific way of arguing".

Erwin Schrodinger pointed out in his masterpiece "What is life?", the basic contrast between the behaviours of the living and the non-living. While increase in entropy (transition from order to disorder) is the consequence of all natural processes in the material world, the phenomena of creation and metabolism which are related to life, operate in the opposite direction. Schrodinger inspite of being a physicist, dared to analyse the importance of consciousness in living objects :

"My body functions as a pure mechanism according to the laws of Nature".

"Yet I know, by incontrovertible direct experience, that I am directing its motions, of which I foresee the effects, that may be fateful and all-important, in which case I feel and take full responsibility for them".

"The only possible inference from these two facts is, I think that I am the person if any who controls the "motion of the atoms" according to the Laws of Nature".

This 'I' is important. 'I' represents the mind, the doer and can not be left out from the scheme of this universe. The Vedanta harps on this problem of 'I', the consciousness in an individual (which is part of the larger universal consciousness), and invokes a scientific analysis of the true nature of 'self'.

Inspite of major scientific progresses in the recent times, we do not yet know the intrinsic nature of 'ourselves'. The human mind, boasting of its stupendous achievements in the material world as the master of modern science, is pathetically stupefied by its own complexity. Alexis Carrel has fittingly remarked in his "Man the unknown":

"The extremely complex science of Psychology is in the state of surgery when surgeons were barbers, of chemistry before Lavoisier, at the epoch of alchemists".

"If Galileo, Newton or Lavoisier had applied their intellectual powers to the study of the body and consciousness, our world would be different today".

Ill-equipped as we are in the knowledge of mental science, how could we pass any expert opinion on the claims related to telepathy, clairvoyance, hypnotism and lastly the mystical and religious experiences, for all of which the mind is the seat of observation'? How could anybody with finite mental capabilities, predict the limit of development for another human mind? Before challenging any mental observation,

we must fully discover the laws pertaining to mind and consciousness. Instead of ignoring the phenomenon of mind, we should explore it. Quite appropriately, J.W.N. Sullivan predicts in his book, "Limitations of Science":

"The science of mind, at present in such a rudimentary state, will one day take control. In the service of the principle of continuity its concepts will be extended throughout the whole of nature. Only so will science reach the unity towards which it is aiming, and the difference, between the sciences of mind, life and matter, in their present form, will be seen to be unreal."

Scientists may however argue that while they never claim the finality of scientific knowledge and admit that there are inadequacies in the science of living body and mind, these inadequacies do not justify religion or the claims of the mystics. Hence, it is necessary to examine how far religion may stand rational or scientific scrutiny.

Mythological beliefs concerning the origin and movement of astronomical bodies and several other natural phenomena are disowned by all modern exponents of religion. However, we should be concerned with the claims of religious or mystical experiences, which constitute the essential core of religion. Personal experiences of the great religious leaders concerning 'supernatural' forces and a 'divine' existence, certainly need corroboration by other individuals. However, a specific kind of mental efforts would be required of those who want to corroborate; and for those who do not wish to exert themselves, certainly no proof would be available. For an effortless person to question religious truth is as senseless as an illiterate farmer challenging the existence of an electron.

Faith is usually disregarded as unimportant towards the scientific search for truth. Yet, as Hume has pointed out, scientific reason is based upon the 'faith' (or assumption) on

religious truth which is a subjective realisation and is reflected only in a cultivated mind, can ever be objectively demonstrated"? Aldous Huxley replied in his characteristic manner, and his statement may be reproduced here in full:

"No subjective experience can be demonstrated. How do you demonstrate music? Religious truth is a state of *mind—Moksha, Nirvana, Satori*—which if you like, you can explain in metaphysical terms e.g. moksha=Tat tvam asi= (in Christian terminology) union with God. But the state of mind is achievable and when achieved, is regarded as supremely valuable, even where no belief in God exists, as in Buddhism.

"All mystical religion (and it is the only kind of religion in which I personally am interested) is operational. It says, 'Perform psychophysical operations a and b. Then (perhaps) state of mind X will be experienced'. By those who care for speculative metaphysics, X can be interpreted in terms of quasi-scientific and purely symbolic statements m and n. But m and n are not ultimately important. What is important is X and the means to X, a and b".*

Thus, it seems reasonable to conclude that religious truths can not be proven objectively. On the other hand, it is unfair to say that subjective proof is no proof. Even the proofs in the domain of science are subjective in the sense that these are evident only to the trained minds. The existence of an electron for instance, is not evident to an illiterate person.

The pursuit of religious truth is no doubt based on the faith that some supernatural forces exist. But then,

* His hand-written note, sent from his Los Angeles residence to the author is dated 19th February, 1961, and has not been reproduced elsewhere. The series of correspondence started after Prof. Huxley had delivered a course of seven weekly lectures captioned "What a piece of work is Man" at the Massachusetts Institute of Technology (5th October to 16th November, 1960).

scientific pursuit is also based on some faith on the inviolable laws of Nature. The elements of reason, experimentation and conclusion are certainly present in both the avenues of search for truth. As the Vedanta points out and as Swami Vivekananda has preached to the modern world, faith devoid of a reasoning and searching spirit does not represent the truly religious mind.

The paradox of the situation is that while Religion can not accept the challenge that its content be proven in the arena of what we call objective or physical science, Science on the other hand hesitates to accept the challenge that it should analyse the phenomenon of religious experience on the ground that the possible proofs are in the arena of subjectivity. The protagonists of Science and Religion may clamour for a fight, so that the superiority of one over the other is established, but they must realise that so long as two 'wrestlers are unwilling to visit their opponent, no dispute can ever be settled. Besides, it could well be that the 'wrestlers' are being unnecessarily provoked by their fanatic proponents!

The 'antagonism' referred to by Herbert Spencer is probably untrue and imaginary. Both Science and Religion have genuine applications as well as limitations. Vivekananda remarked in his lecture on "Religion and Science": "The sage is often ignorant of physical science because he reads the wrong book—the book within; and the scientist is too often ignorant of religion, because he too reads the wrong book—the book without". It may be added that while the genuine sage and the true scientist would accept the limitations of their knowledge in the field which is not their own, this would hardly prevent their unworthy followers from beating the drums of 'antagonism'.

Whitehead emphasized that "the force of our religious intuitions, and the force of our impulse to accurate observa-

tion and deduction" are complementary rather than conflicting. Gerald Holton beautifully strikes the note of reconciliation and finality on the subject, in his article on "The false images of Science" (Saturday Evening Post, January 9, 1960) :

"The way many scientists and theologians state the issue today makes it seem as if we must choose between two normal and powerful drives. This is like forcing a child to choose between his father and mother because they disagree on some matters".

V

Three basic questions were raised in the early part of this article. Arguments have been forwarded in support of the following viewpoints : Religion has not been responsible for the past economic stagnation in our country; secondly, the Vedanta, the basic scripture of Hinduism as well as the Buddhistic texts have favoured and never opposed the cult of logic and experimentation which is the basis of modern science; and lastly, the two cultures of religion and science are not necessarily antagonistic or incompatible.

The true religious spirit that has been a constant feature in the history of Indian culture, can only promote and not obstruct the spirit of scientific enquiry. In ancient India, scientists like Aryabhata, Varahamihira and Bhaskaracharyya had deep reverence towards religion. Similarly, the modern founders of Indian science have never ignored the domain of spirit. Mahendralal Sircar declared in a speech delivered at 1900 :

"I see in the eye of faith that regenerated India has a mission to fulfil in the future. On the stable basis of the physical science, she shall have to build a philosophy and a religion which will be for the regeneration of the world".

It is interesting to note that at the turn of the present

century, many national leaders turned towards religion and monastic spirit for guidance with respect to national rejuvenation including scientific and technological progress. Jagadis Chandra earnestly believed that the Indian spirit of meditation and renunciation for a noble cause could be effectively combined with a vigorous zeal of scientific research in India. Jamshedji Tata had travelled with Vivekananda in the same voyage from Japan to America, and a correspondence from the former to the latter (dated 23. 11. 1898) is worth quoting :

"I trust you remember me as a fellow-traveller on your voyage from Japan to Chicago. I very much recall at this moment your views on the growth of the ascetic spirit in India, and the duty not of destroying, but of diverting it into useful channels".

"I recall these ideas in connection with my scheme of Research Institute of Science* for India, of which you have doubtless heard or read. It seems to me that no better use can be made of the ascetic spirit than the establishment of monasteries or residential halls for men dominated by this spirit, where they should live with ordinary decency, and devote their lives to the cultivation of sciences—natural and humanistic. I am of opinion that if such a crusade in favour of an asceticism of this kind were undertaken by a competent leader, it would greatly help asceticism, science, and the good name of our common country; and I know not who would make a more fitting general of such a campaign than Vivekananda . . . ."

It is truly in Vivekananda, that the noblest aspirations of scientific and religious spirit have been synthesised. Vivekananda realised that for the proper synthesis of the two cultures, the concept of religion has to be rational or else it would not be acceptable to the intellectual and modern

* The scheme achieved fruition in the establishment of the Indian Institute of Science at Bangalore in 1908.

minds. Dogmatism, ritualism and casteism have not only clouded the bright image of Vedanta in our country, but have also brought in a rigid social structure impeding cultural and economic progress of the country. In his lecture on "Reason and Religion" delivered in 1896, Swami Vivekananda prophesied the emergence of a new type of religion, eternally wedded to the rational spirit of enquiry, in the following words:

"Is religion to justify itself by the discoveries of reason through which every other science justifies itself? . . . . . In my opinion this must be so, and I am also of opinion that the sooner it is done the better. If a religion is destroyed by such investigations, it was then all the time useless, unworthy superstition; and the sooner it goes the better. I am thoroughly convinced that its destruction would be the best thing that could happen. All that is dross will be taken off, no doubt, but the essential parts of religion will emerge triumphant out of this investigation".

Indian spirit is eternally dedicated towards reconciliation and reconstruction. It has never forsaken any ancient ideal if it is noble. Whatever the modernists and marxists might preach, religion is probably going to remain an integral part of human civilisation and more so in India. For the sake of economic prosperity and intellectual emancipation, India must be oriented towards scientific research and technological growth. This science-based culture would attain fullness and stability with the central core of reverence and dedication towards the religious truth.

QUO VADIS INDIAN SCIENCE

In the previous articles, the growth of Indian science till the beginning of the twentieth century has been traced. We have seen how the pioneer scientists like Jagadis Chandra and Prafulla Chandra created some atmosphere of scientific thinking and research in the country. Munificent donors such as Sir Jamshedji Tata and educationists like Sir Ashutosh Mukherji and Pandit Madan Mohan Malaviya further widened the path of scientific education and research for the new generations to march on. Between 1914 and 1947, scientific research in India was confined mostly within the four walls of the academic institutions. During this period, industrial expansion has been small and technological research insignificant.

In 1938, Prof. Meghnad Saha perceived the dire necessity of economic planning for national rejuvenation and the paramount role of science in such a scheme. He deserves great credit for having said at that time :

"If we desire to fight successfully the scourge of poverty and want from which 90 per cent of our countrymen are suffering, and to lay the foundation of a strong and progressive national life, we must make the fullest use of the power which a knowledge of Nature has given us".

His concept of national planning on the basis of scientific approach, and his vision of expanding facilities for scientific and technological research were readily appreciated by Netaji Subhas Chandra Bose and later Pandit Jawaharlal Nehru. Since the dawn of independence in 1947, Pandit Nehru, India's first Prime Minister substantially expanded the educational and research facilities, and simultaneously initiated formulation and execution of national planning

through the five—year plans. This has been possible largely due to the inspiration received from Saha and the able assistance from other Indian scientists like Bhatnagar, Bhabha etc.

Current Research facilities and man-power

A recent statistics* compiled by Dr. B. V. Rangarao of the Research Survey & Planning Organisation, Council of Scientific & Industrial Research (CSIR), reveals that there are (now in 1967) in India, 68 universities, 50 CSIR national laboratories, 100 scientific and industrial development laboratories under different ministries and some privately financed, 50 medical research laboratories, 170 agricultural research institutions, 800 agricultural stations—and nearly 2000 units in all, where research is carried out.

It is reported in a census survey† that there were about 400,000 science and technology degree holders in 1961. 30 per cent of the postgraduates and 50 per cent of the agricultural graduates had research assignments. Each year 15 thousand engineers, 6 thousand medical graduates, 6 thousand agriculture graduates and 10 thousand M. Sc.'s in different branches of science graduate from all the universities. From the above figures, Dr. Rangarao has computed that the full-time research workers in 1966 could have been between 60,000 to 70,000 in number. Prof. P. C. Mahalanobis in a recent article‡ furnishes somewhat different figures. According to him, "the stock of scientists and engineers in India with university level education (B.Sc., B.E. etc.) is estimated as 215,000 (of whom 108,000 were scientists, 80,000

* B. V. Rangarao "Scientific Research in India—an analysis of publication", Journal of Scientific & Industrial Research Vol. 26, No. 4, p. 166-176, 1967.

† K. Ray, "Scientific and Technical Personnel Monograph No. 1, Census of India, 1961, Ministry of Home Affairs, New Delhi, 1966.

‡ Symposium on Collaboration between the countries of Africa and Asia for the promotion and utilization of science and technology (CAUUST) Symposium 1966 (held at New Delhi) Report pp. 31-39.

engineers and 27,000 agricultural scientists in 1963), which is larger than the stock in most of the advanced countries with the exception of the USA, the USSR, the UK and Japan. If the diploma level personnel are included, the number would be nearly 600,000 which places India, on paper, in a very favourable position." Prof. Mahalanobis computes that the number of research workers in 1963 could have been around 44,000 (larger than that of France 37,000 or Germany 40,000). He points out however that it is the experience and level of scientific knowledge and not paper qualification which should count. This explains in part why the research output in India may not favourably compare with that in France or Germany. However, the above data serve the purpose of denoting the phenomenal growth of scientific manpower (and facilities) since our independence. It may be pointed out that the number of scientists produced by the Indian universities during the period 1910—1949 was only 17,532 and the number of non-university research laboratories was much less than 50 per cent of the present figure.

Financial support for Indian research

Prof. Mahalanobis pointed out in another article* that while in 1948-49 expenditure on research in India was 10.8 million rupees, the corresponding figure in 1959-60 was 133.7 million rupees (nearly 13 times). In 1965-66, research expenditure in India has been 540 million rupees, and compared to the Gross National Product (GNP) of 235 billion rupees, the research ratio has been only 0.23 per cent. This does not compare favourably with the high 'research ratio' in U.S.A. (3 per cent in 1963) or in USSR (2.3 per cent in 1964). (Although a substantial percentage of financial investment in research in the advanced countries falls under military

* A review of the recent developments in the Organisation of Science in India—Proceedings, of the Sixth General Assembly of the World Federation of Scientific Workers, Warsaw, 27th-29th September, 1959.

research, it can not be denied that much of this military research is of fundamental nature and contributes towards basic understanding of natural phenomena).

Involvement of our nation in scientific research has been stepped up since the independence and yet its magnitude appears so poor in comparison to the endeavour of the developed countries. The low research ratio may be taken as a measure of India's under-development. Stevan Dedijer aptly remarked* :

"Today, over three quarters of the world population from about 130 of the world's 150 countries live in what can be called a scientific desert. Something like 85 % of the world's research resources, including manpower, research units, publications etc. are at present concentrated in about 20 countries, with about 25 per cent of the world's population, each of them investing more than 1 per cent of GNP in research. All the other countries spend less than 1 per cent and most of them less than 0.3 per cent of their GNP on research. The less developed a country is, the smaller the proportion of its investment in research".

A defence of the Indian case might be built around the fact that the average cost per scientist (including cost of buildings, maintenance of supporting staff etc.) in Government institutions in India is around $ 7000 per year, which compares favourably with the corresponding figures in Japan ($ 7000) and USSR ($12000) and the fact that the above Indian figure is 80-90 times the average income per person (in USA the ratio is 17 and in USSR 12). However, the above data are misleading unless properly interpreted. The high ratio (80-90 in India) is due to appallingly low per capita income, and should not serve as an excuse for self-congratulation. Besides, a very large percentage of expenditure on Govern-

* The Science of Science : a programme and a plea, Minerva, IV, 4 pp. 489-504, 1966.

ment research institutions is being currently wasted in pomp and unproductive activities. Hence, there can be no justification for the low research investment (0.2—0.3 per cent of GNP) when we consider that our gross national product itself is very small (17-18 times less than the U.S. annual national income of 500 billion dollars) and that indigenous scientific research instead of borrowed technical know-how is the only means for sustained technological and economic growth of any nation.

II

Quantity and quality of research in India

It may legitimately be argued by our administrators and politicians that after all the research investments expressed as percentages of GNP are not very high in some scientifically advanced countries like Canada (0.9 per cent in 1963-64), Denmark (0.5), Italy (0.3) etc., which have also less scientific personnel (Canada 10,000, Denmark 2400, Sweden 19,000 etc.). Therefore, it is pertinent to assess the scientific output that we have achieved in recent years, particularly in the light of the investments made so far.

Dr. B. V. Rangarao has conducted a survey of all the technical publications authored by Indian workers and mentioned in the Indian Science Abstracts in 1965. During this one year period, 9804 publications were reported, of which only 5948 were research papers and the rest were short notes or review articles. Contributions to foreign journals have mainly been in Physics and Chemistry (282 and 207 respectively out of a total of 891). From the above statistics, it is computed that the productivity of the publications is at the rate of one paper for 6-10 scientist-years effort. Considering that 65 per cent of the papers published by the Indians has been by single authors and that the average number of authors in a technical publication stands at only 1.76, it is quite obvious that a very large fraction of scientific

personnel is extremely unproductive and to that extent, research expenditures on personnel and facilities in our country are being wasted.

Dr. Rangarao further points out that out of 2000 units of research, 44 institutions contributed 50 per cent of all the publications of the country and 12 of them including University of Calcutta, Banaras Hindu University, Delhi University, Indian Institute of Science, Bangalore, Atomic Energy Establishment, Tata Institute of Fundamental Research, and Indian Agricultural Research Institute, more than 25 per cent. Publication activity is much higher in universities but not in technological institutes. Although we have nearly 70 universities, there are only 13 universities from which more than 100 publications were contributed during the year under purview. The presence of a large number of research students working for degrees appears to be the main reason for a high proportion of the papers being published from universities. Research papers in engineering subjects are very low in number. In the future, the annual statistics would differ from year to year, and yet the general pattern may still continue.

It is quite obvious that there are only narrow pockets in the Indian scientific community, where original investigation is practised to any extent. Ninety per cent of the research personnel and research units in our country is unproductive and there is no reason why this ninety per cent of the scientific community can not follow the example of the other ten per cent. This colossal wastage of scientific manpower and facilities must be investigated and immediately rectified or else we are destined to live in what Stevan Dedijer termed as "scientific desert".

While nine out of ten scientific workers in our country remain idle spectators of science, or engage themselves in activities which are in the ultimate scientific analysis fruitless,

the morale of the lone one out of ten suffers and the result of his scientific efforts may not be spectacular. This is borne out by the quality of scientific research in India, which has been characterised as low by many reputed scientists of our times.

Prof. T. M. Oza wrote an interesting article on "The Contribution of Indian Chemists to the progress of Chemistry" (Vijnan Karmee Sept. 1958) drawing references principally from the Annual Reports on the Progress of Chemistry published by the Chemical Society, London (1904-1956). Prof. Oza rightly pointed out that the annual British Review is reasonably impartial and trustworthy, and that the assessment of the Indian contribution to Chemistry by the impartial reviewers is reliable. During the aforesaid period "there have been barely 120 chemists from India with five or more than five papers mentioned in the British annual reports. This figure is incredibly small and yet it includes chemists also as subsidiary workers (working with foreign principal collaborators) ...... The writer (Prof. Oza) is aware of some chemists who have over sixty publications to their credit with less than two mentioned in Annual Reports. Some of these persons may be found to hold very high positions".

During 1910—1955, about 29,000 science graduates have been produced by the Indian universities and approximately one-third of this number have been chemists or chemical technologists. It is a pity that out of several thousands of trained chemists, only one hundred have achieved any mentionable recognition outside the country ; this is a sad commentary on not only the quantity but also on the quality of Indian research in Chemistry. With the exception of the contributions of half a dozen outstanding Indian physicists, the quality of Indian research in Physics does not also favourably compare with the world standard. The trend is as bad if not worse in other fields of science and technology.

Shortcomings of the present set-up

It must be admitted that the wave of Indian science which was in its formative stage in the early part of the twentieth century has failed to inundate the Indian social and intellectual life. Jagadis Chandra's and Raman's example hardly inspire the modern youth of India today.

The bureaucratic set-up must be largely responsible for the apathy, frustration and lack of morale amongst the young scientific workers of our country. Dr. Kurt Mendelssohn, F.R.S., of the University of Oxford in his talk on 'Science in India' praised young Indian talents in science ,who were suffering from "lack of appreciation of their work ; insufficient means for research ; difficulties in obtaining equipment, and last but not least, pettiness and jealousy among colleagues particularly the older ones".

Dr. Punya Sloka Ray brilliantly put forth "The case of the frustrated scholar" in the Statesman (Dec. 31, 1959) :

"The older academician, the man who was once a scholar and is now merely an empty shell is a familiar phenomenon in India today. Often he is just harmless. At best this type of man is not prepared to listen to anything which he was not familiar with in that by-gone period when he had not yet lost the habit of inquiry. When a young man brings up ideas, he meets it with cultivated and dignified deafness. At worst, he is jealous of any tangible achievement or constructive proposal that come from his junior colleagues or even his own students. He tries to stop them, if not to steal them.

"We young scholars know that the odds against us are heavy. When we consider that, because of the absence of books, journals, instruments and the leisure to use them, we fall behind our contemporaries abroad year by year, that it will take us years to achieve what they do in months, that we are in a race with millstones round our necks, our hearts feel

like bursting......... There are so many who would counsel us to be prudent, to stick to the good old way, to have a permanent job with automatic increments and sit in an easy chair. Should we listen to this advice ? Or, should we, one by one, escape to some other country where research is honoured ?"

Prof. J.B.S. Haldane the famous British biologist who accepted Indian citizenship, has expressed similar views, with more anger than anguish, in his book "Science and Indian Culture" :

"Perhaps some Indians remain abroad for the reasons stated by Mr. Nehru ("for better inducements and facilities"), but others do so for very much more honourable reasons. Every scientist who is worth anything has a double loyalty, to science as well as to his country. In India there are numerous laboratories where scientists are forbidden to work. I can think of one where a worker drew Rs. 400/- per month for at least six months without doing anything but filling in forms about work in contemplation and showing visitors round ......All over the country, junior workers are regarded with jealousy by their superiors, who either discourage originality or steal its results. I recently saw a bibliography of publications by the head of a well known Indian laboratory. This remarkable man had published over fifty scientific papers in one year. No single human being before him has ever made discoveries at this rate ! No doubt junior colleagues had done most of their work or all of it. But their names were not mentioned".

"It is not surprising that young men do not care to work under such conditions, particularly, if like the unfortunate agricultural scientist who recently hanged himself in Delhi, they are forbidden to apply for posts elsewhere*. So long as

* Dr. M. T. Joseph, a teacher in the Entomology Department of the Agricultural Research Institute, Pusa, Delhi, committed suicide in January, 1960. With a doctorate degree and 15 years' research experi-

the Government departments concerned do nothing to discourage persons responsible by cutting down grants, and by other methods which are available to them, bright young men will take jobs abroad. The Prime Minister (Nehru) himself is not wholly free from responsibility. He has certainly given his blessing to laboratories which produce very little work of any value, and use up a lot of foreign exchange, while training young men very badly indeed".

A paradox in the current Indian situation is that while more and more investment is being made on the research apparatus in the country, the atmosphere for original and fruitful scientific investigation is getting stagnant if not worse. It is imperative that greater consideration must be shown to the scientist himself than even to the laboratories and to the equipment, which are merely tools for his research. There must be an accurate assessment of the need and corresponding plans for raising scientific manpower of desired magnitude and quality. Only then the epidemic phenomenon of 'brain drain'—the ceaseless emigration of Indian scientists to foreign countries could stop. Young scientists would feel encouraged to join and enrich the profession of scientific research in India only if proper leadership is available from (a) scientists of established reputation (b) professional organisations and (c) the society at large. We may examine each of the three sources of inspiration and comment on the existing Indian situation.

The decadent leadership

It is known that leadership from individuals directs the scientific progress of a country in two following ways :

1. It moulds the collective leadership and is supremely important when and where the latter is absent. Amidst an

ence, he was employed in the grade of Rs. 160-10-330 and not allowed to take up a better job elsewhere prior to completion of lengthy procedural formalities.

environment of indifference and apathy towards science, Mahendralal, Jagadis Chandra and others created avenues of scientific research for the benefit of future generation. With the passing away of Pandit Nehru, the creator of national laboratories, Prof. Meghnad Saha and Prof. H. J. Bhabha, India does not have at present suitable leaders who may *conduct* the future growth of Indian science.

2. It is mainly responsible for initiation of schools of research. Contributions of individual schools of scientific research to the overall accumulation of scientific knowledge are of immense importance and obviously depend upon the initial formation of such schools and their uninterrupted maintenance through able successors. Rudloph Sachtleben mentions in an article (Journal of Chemical Education, February 1958) that of the Nobel laureates in Chemistry, 34 are lineal descendants of Liebig's school and if the Nobel awards had been started in 1850, the number of Liebig's 'descendants' included in the list of Nobel laureates would have been surely greater. Only the outstanding scientists can initiate such schools, and by virtue of their experience and constant association with the frontiers of science, can successfully initiate the juniors in scientific endeavour. Acharyya Jagadis Chandra emphasized this point so beautifully :

"There must be favourable combination of circumstances for success in research. You must first have as the teacher one who after long seeking has found; who has seized boldly as it were, the thorns that beset his own path in the hope of making a little easier for those who should come after. This is the man who alone can kindle enthusiasm in his disciples. A candle can be lighted only from another burning candle".

It is a matter of deep regret that even the research schools initiated by Acharyyas like Jagadis Chandra,

Prafulla Chandra etc., have not sustained their glorious output. During the last three decades, and particularly since independence, many promising scientists have abandoned their active research careers in preference to administrative jobs. The posterity will give its verdict as to whether the migration of active scientists and their involvement in various non-research administrative work, has been a gain or loss to the country, in the overall analysis. There might have been some need for a few scientific experts to remain outside the laboratory and help the Government in formulating policies for scientific development of the nation. However, the large-scale migration of scientists away from their laboratories has been an acute deterrent against the desired growth of Indian science during the last few decades.

Eminent scientists such as Fischer, Perkin, Ramsay etc. never accepted a directorial job in any scientific institution unless they were ensured that the requirement for their attendance to committee meetings would be strictly limited to the minimum, so that they could devote most of their time in research and training the juniors. Even in our country we have had the glorious example of Acharyya Prafulla Chandra who checked the temptation of entering in politics. He said:

"When there would be thirty chemists in India, I will consent to give up my work and enter politics. There are too many politicians in India, but we have not enough chemists. I am deeply interested in politics. I am interested in so many directions but every fraction of a second, I give to other things is so much robbed from my Chemistry and my work suffers".

Inspite of the numerous noble examples, the contemporary Indian scientists of our times are showing more keenness towards administrative and bureaucratic jobs than

to their profession. Scientists have been turned into administrators engaged in a race for promotion and recognition.

The Spectator (20th May, 1960) has given a very candid picture of what is happening to the scientific community of our nation. The scientists are grouping themselves "in a hierarchical order. At its top are the super-scientists. They move closest to the nucleus—the nucleus being the Government. As the orbits are small, they have to be only a few. But they have tremendous power and patronage. They are the know-alls and have-alls. They have built up their own empires in laboratories, councils, seminars and committees. They observe an unwritten understanding not to tread on one another's toes. They come down heavily upon imaginary or possible rivals. Even as they cling to power and work smoothly for pelf and parks (including free trips abroad, preferably in summer) they create an impression of being detached and saintly if not other-worldly. They do little work. But effective public relations, which incidentally will bring them good chits from foreign scientists, enable them virtually to live a life of rich indolence".

With great sarcasm as well as remorse expressed as an Indian citizen, J. B. S. Haldane commented: "A large number of Indian scientists have no pride in their profession, though they are proud of their salaries and positions. The opposite attitude is common in Europe, *as it was in ancient India* . . . . . . In India today the unworthy successors of Durvasa and Visvamitra actually invite Governors, Vice-Chancellors and the like, to address them (at the Science Congress)".

Apart from the low quality of leadership from those who are at the helm of scientific affairs, we are also witnessing the miserable plight of professional organisations in our country. National scientific, engineering and medical associations have hardly raised their voices to correct the deteriora-

ting standards of education and research in their subjects. This is however not surprising since these associations hardly listen to the angry young idealistic scientists and are almost completely controlled by those grey hairs who have long shifted their loyalty from science to bureaucracy and self-aggrandisement. National scientific bodies like the National Institute of Sciences and the Indian Science Congress Association etc. have to accept major responsibility for letting Indian science drift downward in the scale of standards. Prof. Haldane has ruthlessly exposed "the scandal of the Science Congress" in his famous article. He wrote:

"At Bombay the Science Congress appeared to be an organized conspiracy against originality in Indian science... It is time that responsible persons in India realised that the invitation of foreigners to such congresses lowers the prestige of Indian science considerably".

It is quite clear that there is a crisis of leadership in Indian science. Our nation does not lack in idealism particularly for science. However this idealism amongst the young aspirants is nipped in the bud due to the unwholesome atmosphere where we see organised groups of "sycophants, snobs, scientist-politicians and self-seekers" putting a spoke in the wheel of scientific progress in our country.

III

Crisis in education

That the Indian science is not progressing satisfactorily is also largely attributable to the mediocrity and indifference in the educational and social atmosphere. How can any society or any nation expect scientific progress when the young graduates have not been equipped with the necessary modern scientific knowledge, the general educational level is far below world standard, and above all, there is little grass-root appreciation or popular demand for indigenous science?

Since independence, educational facilities have been considerably expanded in India. In 1950, 23 million Indian children of the ages 6 to 17 went to school; today over 70 million do so. We have nearly half a million schools with 2 million teachers. Literacy percentage (14.5 p.c. in 1947) has more than doubled in two decades.* The number of students in colleges (in 1967) is nearly 1.5 million—five times more than in 1951. The number of universities has nearly tripled in the two decades of independence (25 to nearly 70 in 1967).

However, this expansion in magnitude has not been accompanied by improvement in quality of education whether in the school, collegiate or university level. At almost every stage, the syllabi are outmoded. Greater stress is given on memory work than on basic understanding. There are not enough teachers who have the competence or determination to teach effectively on modern lines. Even competent teachers are getting obsolete in terms of newly discovered scientific knowledge. Thus, the science graduates of our university find themselves hopelessly unequipped for modern scientific research.

Dr. D. C. Pavate, Vice-Chancellor of Karnatak University said in a convocation address delivered in 1964 :

"Whenever I go abroad, I make it a point to meet our students (Indian students) and the professors under whom they work. The students invariably complain against outmoded courses of study in their home universities and the consequent handicaps from which they suffer abroad. It is true that some of our students have achieved great distinction in Physics, Chemistry, Mathematics and Biological sciences in Europe and USA, but by and large, they have to struggle hard owing to their inadequate foundation at home...... Broadly speaking, our Master's degree course falls far short of the requirements of the Honours and Bachelor's degree in Great Britain and Canada. In addition the sylla-

bus in Physics, Engineering and Mathematics in many of our universities is at least 25 years behind the western requirements". A sad commentary on the state of scientific education in India, indeed!

Much more revealing facts are disclosed in the University Grants Commission (UGC) report on "Standards of university education" (New Delhi 1965). For example, a "recent survey of the Physics (Honours) curriculum in one of the universities of India revealed that 75% of the material taught to them was exclusively concerned with the nineteenth century physics and the remaining portion with the physics of the first two decades of the present century". The UGC report gives a relevant warning :

"Until we are able to ensure that colleges are not set up without fulfilling certain essential conditions relating to facilities, staff, resources and organisation of studies, the field of higher education will continue to contain cesspools, capable of contaminating large areas in it".

It is well known that bright talents are hardly attracted to the teaching profession in view of the difficult working conditions (such as unfavourable teacher-student ratio of 1 :17.3 in the universities and 1 :30 in the undergraduate colleges) and particularly low emoluments. The UGC report boldly asserts :

"The problem of salary of teachers is acute. We are of the view that the first priority on the part of the State Governments in the matter of financing universities and colleges should be to regard the UGC recommended pay scale as committed expenditure.. . . . It will be necessary to review the scales of pay from time to time keeping in view the rising cost of living. . . . .

"It must be understood that in a highly competitive wage situation, and of continually rising cost of living, appeals

to the 'spirit of dedication and sacrifice' on the part of teachers cannot effectively solve the problem".

It is really dangerous to expand higher educational facilities any further without ensuring attractive salary and working conditions for teachers, and recruitment of sufficient number of competent teachers, dedicated towards advancement of learning through research.

The problem of education and science teaching in particular in Indian schools is decidedly much more acute. Competent science teachers, equipped laboratories, suitable audio-visual teaching equipments etc. are all sadly lacking in the Indian schools. Science teaching in the universities can not be made effective unless the entrants have received sound knowledge in science at the earlier educational levels.

Prime Minister, Srimati Indira Gandhi convened a round table discussion on "the crisis of Indian science" (September 7 & 8, 1967), and on that occasion, she quoted from a letter written to her by one eminent foreign scientist, who had recently visited India :

"Much of what I saw was wonderfully good ; for example Trombay, the Tata Institute etc. . . But the same is not true of the overall plight of scientific education in schools and universities".

"The failure of science to take hold in schools and universities and indeed its strangulation by traditional subjects there, can only be reversed by setting much higher targets for scientific education than those now planned. The targets proposed at present are too low and too slow. They cannot push science ahead of the economy and turn it into an industrial leader. Science and all aspects of truly modern education can forge ahead in India only if far-sighted minds accept the thesis that it must be given a disproportionate share of the national cake now. Only so can the national cake itself grow faster in the future. The cost of scientific education

must be accepted as a long term investment in the economic future of India".

Superficially, it may appear strange to some administrators and thinkers that inspite of 100-200 per cent expansion of educational and research facilities since independence, the chariot of scientific education and research in India has not moved very far. To clarify this anomaly, it may be pointed out that even now, investment in education as compared to the Gross National Product (GNP) is barely 3 per cent. For the third five year plan, total allocation of foreign exchange for technical training and laboratories was only 250 million rupees which was barely one per cent of the foreign exchange received through aid and exclusive of exports.

In view of the poor financial resources of the nation, one may not consider the expenditure on education as insignificant. One may however question whether we have made the best use of it and what fraction of this money has been utilised to upgrade the pay-scale of teachers at different levels so that competent and talented people could be attracted to this profession. Somehow, appropriate monetary and psychological incentives must be provided to the teaching and scientific profession or else labouriously built laboratories would remain empty and equipments purchased at great cost shall remain unattended and get rusty.

IV

The interfaces between science and society

Science and society influence each other and if any nation is to be profited by science, then it must ensure strong mutual interaction and active interfaces between science and society at (a) the popular level and (b) the economic level.

(a) The popular level :

Popularisation of science is a crying need in any part of the world and more so in India with 70 per cent of its inha-

bitants being illiterate. Our countrymen must be made to understand the revolutionary changes in human civilisation ushered in by the impact of modern science. They must be told how scientific knowledge is going to help them in improving agriculture, health, industry and commerce. They must be made to acquire a scientific and rational outlook, free of preconceived notions and superstitions, so that any national problem may be squarely faced and adequately solved.

Popularisation of science, particularly in half a million Indian villages, should proceed hand in hand with drives for adult education, family planning and health programmes etc., and young students must be exhorted to contribute their mite in this gigantic task of national construction. The idea of 'Vijnan Mandir' or a rural scientific laboratory has been beautifully conceived—and with adequate number of these mandirs and requisite scientific kits and dedicated volunteers, Indian society can be rejuvenated with success, hope and vision. In return, the benefited and grateful society is bound to pay greater respect to science and extend all possible encouragement and assistance for the younger generation to pursue this noble profession. National programme of this sort must be worked out in meticulous details and executed with speed and vigour.

(b) *The economic level* :

National economy is inseparably related with science and technology. If a nation is to prosper, agriculture, industry and commerce taken together should benefit the growth of indigenous science and be benefited in return. In India, we are still in the take-off stage and hence we must ensure that indigenous science and industry develop a healthy interface between themselves for mutual prosperity.

Prime Minister Srimati Indira Gandhi has recently confessed that there is "inadequate contact between science and

industry" in our country inspite of 20 years of governmental patronage to both. Since independence, factory production has been stepped up by nearly 20 per cent and large sized steel mills, fertilizer plants, heavy machinery plants, oil refineries, locomotive works, atomic power plants etc. have been established largely with foreign aid and collaboration. Simultaneously, a chain of national laboratories has been established and investments on scientific research stepped up with the hope that Indian industries would be helped by scientific and technological investigations. However, Indian industrialists often "look upon the governmental laboratories as unnecessary white elephants and are more than critical when they are obliged to adopt technology developed in the laboratories and foreign collaboration is denied by the Government".

Each developing nation has to lean on borrowed technology and imported technical know-how in the initial stage. But this does not mean that the nation has to remain chronically dependent on foreign help for indefinite time period. The earlier the concept of self-reliance is implemented, the better for the nation. Sri Hari Bhushan of the Planning Commission has brilliantly exposed (in his article "Science round table" published in Vijnan Karmee, October 1967) the fallacy of "the lure or the *mrigmarichika* of the availability of foreign credits on easy terms of interest and repayment". He writes :

"We can go after the golden deer but will get our *grahlaxmi* (prosperity) stolen. It is important to realise that the term 'assistance' by foreign countries is somewhat a misnomer. What is offered to us is credit leading to indebtedness ......We are heavily debted today. We are even asking for further credit to pay the interest on our debts .... The attraction of credit combined with the preference for the imported technology, equipment and foreign experts exclude to a large measure the scope of the fruition of the hard work and

labour and consequently job satisfaction which our scientists and technologists so badly need and only which can perhaps provide sufficient attraction to retain them in the country."

Around ninety per cent of the patents in India are owned by foreign interests. This is in contrast to the situation in Japan which has never permitted (even in its developing stage) control of technology by foreign interests. There is no reason why we should not try to make outright purchase of technical know-how and design, even at some enhanced cost, so that we may use this repeatedly for installation of similar equipments. We should insist that our scientists and technologists should be associated with the foreign collaborators at all stages of design and erection of plant even if this means that the financial terms become stiffer.

The advantage of foreign technical collaboration, justifiable only in the initial stage of a growing economy, is lost through repeating it second and third time and failure to develop our own indigenous know-how. Indigenous efforts must be preferred to foreign collaboration (which should not be permitted unless it is indispensable). For the indigenous efforts there shall be wastage of time and resources and many disappointments in the initial stages, as evident from the history of the growth of technology in any country. However, this will be a small price for providing a base for further industrial growth.

Indian industries must be persuaded, and coerced if necessary to set up their own research and design facilities. A suggestion has been made at the CSIR Get Together with industry held in December 1965, that a levy should be enforced on industry to set aside funds for research and development. "The funds so earmarked should be collected by Government only if the industry does not spend it on research and development within its own campus or elsewhere". As early as 1958, the author wrote in the editorial of 'Vijnan Karmee'

that "the industries must have their own research units and own scheme for training of personnel and development for the future". It is high time that our Government bridges the gulf between science and industry and establishes a high power executive machinery which would coordinate and direct all future industrial growth and scientific and technological research activities particularly in the national laboratories. It is also imperative that this machinery should be manned by scientists, technologists and industrialists of proven competence and integrity, and that this body be allowed to adopt impartial decisions and implement the same without inhibition. Our industries can not grow indefinitely without continuously receiving know-how from indigenous science and technology, which again can hardly develop without increased financial patronage from the industries. Science and industry in our country must have a synchronised and symbiotic growth or else both would perish.

V

The problem of scientific and technological education and research in India has indeed different facets, as illustrated earlier. It would be futile to concentrate on one aspect of the problem, disregarding others, since the parameters are intimately interconnected. Let us illustrate the point just made.

Inadequate financial support to education and research cannot tone up the general intellectual atmosphere in the country and can not attract the bright students towards the profession of scientific teaching and research. As a result there is a deterioration both in the standard of scientific teaching as well as the quality of students graduating out. Naturally, the element of excellence in research in the country becomes a scarcity. The industries and agriculture remain hardly benefited and the society at large becomes apathetic

and reluctant to increase its financial commitment towards science and education, which has hardly been adequate at any time in the first place. This kind of vicious circle (or downward spiral) operates in most of the developing countries including India. Increased financial support to education and science coupled with careful planning and vision can certainly reverse the trend and spur the growth of fruitful science and prospering economy influencing and invigorating each other in an upward spiralling fashion.

There is an urgent need of a comprehensive national policy on science and education. Prime Minister Nehru certainly took the pioneering step of recognising the supreme role of science and technology in building a modern India. Apart from being instrumental in establishing new universities and a chain of national laboratories, he gave due recognition to the cause of science by proposing the "Scientific Policy Resolution" which was adopted by the Indian Parliament on March 12, 1958.

Even a partial extract would reveal the lofty spirit of the resolution :

".........In industrialising a country, a heavy price has to be paid in importing science and technology in the form of plant and machinery, highly paid personnel and technical consultants. An early and large scale development of science and technology in the country could therefore greatly reduce the drain on capital during the early and critical stages of industrialisation."

"Science has developed at an ever-increasing pace since the beginning of the century, so that the gap between the advanced and backward countries has widened more and more. It is only by adopting the most vigorous measures and by putting forward our utmost effort into the development of science that we can bridge the gap......... The Government of India have decided to pursue and accomplish these aims

(promotion of science, training of personnel of highest quality etc.) by offering good conditions of service to scientists and according them an honoured position, by associating scientists with the formulation of policies, and by taking such other measures as may be deemed necessary from time to time".

The pious resolution was put forth with vision but never implemented with any vigour. Srimati Indira Gandhi, our present Prime Minister told a group of scientists on September 7, 1967 :

"It was under his (Nehru's) inspiration that Government adopted a Scientific Policy Resolution in 1958. But there we have stopped. This is really my concern and the need I felt for calling such a Round Table because I am getting numerous letters from visitors to our country as well as eminent scientists in other countries who write practically accusing me that nothing has happened for these several years and that we have not progressed further".

It is quite obvious that mere lofty resolutions, however well-motivated these might be, can not solve the problems of Indian science. The implementation, *all-out implementation* it may be emphasized, of a comprehensive plan for science is the urgent necessity. The 'comprehensive plan' must envisage increased financial commitment of the nation towards education and scientific research ; revolutionary changes in the educational set up, starting from the primary school upto the university level, emphasis on refresher courses at all levels to stem the obsolescence of scientific personnel; perfect coordination of scientific research in different spheres ; augmentation of suitable monetary and psychological conditions so that bright talents are attracted towards the noble profession of science ; integrated planning for the right magnitude and quality of scientific manpower in the country as well as a judiciously worked out overseas training programme ; and lastly, a

built-in mechanism which ensures that only the brightest (from any strata of society) should move to the top, and that perfect objectivity governs all decision-making in science. Such a plan is difficult to make and even harder to implement. But without an all-embracing approach such as the one described above, only patch work could be given to the wounds in the body of Indian science, the wounds would possibly never heal and Indian science can at best limp and never progress with the desired speed.

Science-planning organisation

There must be one supreme national body for science-planning in our country bestowed with advisory as well as executive capacities.

At present, we have Research Survey and Planning Organisations (RSPO) working under the Council of Scientific and Industrial Research (CSIR) and the Department of Atomic Energy, as well as the Scientific Research Division of the Planning Commission (SRD/PC) engaged in problems of national planning in science. The most significant body however is the Scientific Advisory Committee to the Cabinet (SACC). This committee was established in 1956. Composed of fifteen scientists and technologists, this committee is entrusted to advise the Cabinet "in the formulation and implementation of the Government's science policy". Very often they are in half a dozen decision making committees besides SACC and also act as heads of different scientific organisations. As a result, vested interests creep in and objective decisions are rarely taken. Responsible and reputed scientists like Profs. H. J. Bhabha, D. S. Kothari, P. C. Mahalanobis etc. have expressed their unhappiness over the composition of SACC, and executive committees of National Institute of Sciences.

There is a widespread feeling amongst Indian scientists

and technologists, and rightly so, that science planning has become the monopoly of a top few whose watchword is self-congratulation. The scientific community at large, is being by-passed in decision making on agricultural, industrial, research and educational policies. In contrast, Japan has a highly democratic body viz., Science Council of Japan (JSC), which advises the Government on science. The 210 members of the Council, 30 from each of the seven divisions like pure science, engineering etc., hold office for three years and are elected by a *nationwide* constituency of science graduates and researchers. Such a democratic set up in science-planning bodies is essential towards healthy development of science traditions in our country. Education Commission has rightly commented in its report :

"In these days when science impinges on broad issues of economic and national problems, it is desirable that a national organisation of scientists is not controlled entirely by the scientific aristocracy, as it were, but the entire scientific community gets a chance to participate in the life and work of the organisation."

The democratic set up of science organisations would help in elimination of bureaucracy and self-seekers, usher in objectivity as well as purpose in national science planning and eventually induce emergence of competent scientific workers, who in turn would give effective leadership to these organisations and the nation in the matters of science. But would the bureaucrats in science be interested in creating such a democratic set-up, or the Government has to step in frequently and put the house of Indian science in order? The eternal questions are : who shall educate the educators, teach the scientists to be more scientific and govern the Government in the matters of science. Somehow, as in all human matters, the system has to evolve a mechanism of rectifying its own defects.

VI

Socio-political factors and Indian science

It is well-recognised that for mutual prosperity, Science and Nation must benefit each other. In the ancient India upto the eighth century, the Hindu and Buddhist rulers extended royal patronage to education and science. Scientific discoveries by Aryabhata were possible largely due to the appropriate intellectual climate characterised by political stability. In return, scientists (conditions were not yet ripe for the emergence of modern technology) tried to render yeomen's service to the nation particularly in the fields of agriculture, medicine and astronomy in their humble way. This cycle of reciprocity might have continued; however, adverse political factors dealt a death-blow to science in the mediaeval India. The history of emergence of modern science and technology in the Western countries and in Japan teaches us similar lesson viz., optimum economic and political factors are necessary pre-requisites for scientific development which again influences national prosperity.

Can the present socio-economic and political factors in India be considered as conducive to sustained growth of Indian science and technology? It is doubtful whether a clear affirmative or negative answer to the above question could be given. The previous discussions however help us to seek an answer on the basis of two considerations : (a) whether Indian economy and political leadership would permit substantially increased and sustained financial commitment towards science and education and (b) whether the present conditions are suitable for the emergence of 'leaders' of science who may pull Indian science out of the miserable rut.

The present Indian economy

If our Indian economy has not progressed in the twenty years of independence, inspite of 62 per cent increase in food

production, 150 per cent in industrial production and so on, the phenomenal growth of population can be cited as the principal obstacle. Per capita income (at constant 1948-49 price level) has risen by only 25 per cent from Rs. 250 to Rs. 312 through the three five-year plans. This slow growth of economy is due to alarming rise in population (2.5 per cent rise a year) which has shot above 500 millions mark and might reach 650 millions in 1975-76 and a billion by the end of this century! It would be a pity if science which should be fully utilised to solve the population problem, is allowed to suffer owing to the economic difficulties arising out of the same problem.

Our country is deeply buried in foreign debts. Aid received from the foreign countries and international institutions amounted to $ 11.7 billions by 1965. 'The Financial Times' of London has quoted (22nd December, 1967) from an unpublished report of a World Bank mission which visited India in July, 1967 :

"The overall balance of payments deficit this year should be about $ 1.8 billion dollars and will continue to rise and the outlook for higher export earnings is gloomy. . . . Even for a country as accustomed to economic difficulty as India, the present situation on the Indian economy can be described as unusually difficult".* On the top of it, heavy defence expenditure has put additional strain on our economy.

Obviously, we have made mistakes in our national planning, particularly in the areas of population control, mobilisation and motivation of manpower (there is a tendency to fall back on foreign aid instead of self-reliance), agriculture and lastly education. It may be argued that in view of our limp-

* In this connection, it may be noted (as pointed out by Prof. P. C. Mahalanobis) that China with a fifty per cent bigger population than India, and an equally stagnant economy in the forties, attained a self-sustaining economy with the help of foreign loans of only $2.3 billion dollars spread over 7-8 years.

ing economy, increased financial commitment towards scientific education and research would be a difficult proposition. Nevertheless, our nation must help science in order to be helped in future and hence, increased financial responsibilities towards science must be undertaken.

More important than monetary investment is a moral concern for the quality of research and research personnel. It has been amply demonstrated that attainment of improved quality of scientific research would be nearly impossible unless the entire educational set-up (particularly science education from the primary school stage to the university stage) is toned up and the professions of education and research are made sufficiently attractive in terms of money and social prestige.

Thus, it is quite apparent that even the question of emergence of a large number of competent science educationists and researchers hinges critically on the ability and will of our society and government to extend increasing patronage in the fields of science and education.

Apart from the economic hardship, our nation is plagued with the diseases of political instability, linguistic chauvinism, regionalism, bureaucracy and above all concentration of wealth and corruption. In a country, where not even five per cent population can save any money, not even one per cent earns enough to pay income-tax and yet most of the wealth is concentrated amongst 0.01 per cent of the population, to expect too much idealism and dedication from teachers and scientific workers would be most unrealistic. Unless and until true democratic socialism is implemented and genuine justice, equality and honesty prevail, the motivational factor of idealism, which is worth billions of currency notes, would hardly emerge amongst Indian masses and in the community of scientists. A socio-political change is essential for the growth of Indian science.

Nevertheless, it would be immoral on our part to end with a note of pessimism, for that would amount to losing confidence in ourselves. While it is true that a defective society is not conducive for producing suitable leaders in the different walks of life, it is also true that even in such a society, outstanding individuals emerge with burning spirit of idealism and transform the society and the nation. This has happened on numerous occasions in India. The examples of Rammohun, Jagadis Chandra, Gandhi etc. illustrate how the bold intellectual traditions generated by individuals can serve as beacon-light for the subsequent national rejuvenation. If we, the educated people in our country become introspective and conscious of the national needs, and properly discharge our individual, professional and social responsibilities, then suitable leaderships would certainly emerge in different walks of life, and new generations of scientists and technologists shall firmly establish our country on the scientific map of the world.

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INDEX

Abdul Latif Khan, *56*, 78
Abu-l Fazl, 25, 26
Agnivesa, 4
Akbar, 25, 26, 29
Al-Battani, 9
Albert Temple of Science, 58, 59
Al-biruni, 14, *20*, 22, 101
Ali Mardan Khan, 27
Ancient Indian numerals, 13
Aryabhata, 3, *10*, 17, 102, 116
Aryan civilisation, 2
Asiatic Society, *34-35*
Atreya, 4
Aurangzeb, 27, 30

Bakshali manuscript, 13
Bernal, J. D., 10
Bhabha, Homi Jehangir, *96-97*
Bhaduri, Chandra Bhusan, 90
Bhaishajyaguru, 7
Bhaskaracharyya, 11, *12*, 23, 116
Bhatnagar, S. S., 93
Bhela, 4
Book Societies, 39, 47
Bose, Chunilal, 60, 65
Bose, D. M., 89
Bose, Jagadis Chandra, 35, 61, 75, 78, *86-89*, 117, 129
Bose, Pramathanath, 60, 78
Bose, Satyen, *95*
Bose, Subhas Chandra, 119
Brahmagupta, *11*
British India Society, 40

Carey, William, 36, 41, 46
Chandrasekhar, Subrahmanyan, *97*, 98
Charaka, 4, *7*, 40
Chatterjee, Aghorenath, 85
Crescograph, 89

Datta, Aukshoy Kumar, 49, 50
Dey, B. B., 92
Dhar, N. R., 91, 92
'Digdarshan', 36

Elphinstone, Mountstuart, 41, 42

Filliozat, Jean, 9
Fort William College, 37
Fowler, 93
Fukuzawa & Japanese Science, 31, 39

Gandhi, Indira, 135, 142
Ganesa Daivadhya, 14, 15
Ghosh, J. C., 93
'Gleanings in Science', 47
Greek Science, 3, 4
Gunpowder, 19

Haldane, J. B. S., 98, 127, 128, 131 132
Harappa Civilisation, 1, 2
Harit, 7
Harrington, J. H., 37
Harun, 7, 14
Hastings, Warren, 34
Hindu astronomy, 2, 3, 8
Hindu chemistry, 14
Hindu College, 40
Hindu geometry, 3
Hindu mathematics, 8, 10
Hindu medicine, 4
Hindu metallurgy, 14
Hundred years' progress (1757-1857), 46-48

Indian Association for Cultivation of Science, *55-66*, 71-74, 81
Indian Institute of Science, 62, 93, 117
Industrialisation in India, 49, 91, 119, 138-140
Industry & Trade in ancient India, 16, 101
Industry & Trade in mediaeval India, 19, 23, 27, 34

Jagadis Chandra, *See* Bose
Jagannath, 15, *27*
Jai Singh, 15, 24, *27*
Jatukarna, 7
Jivaka, 4
Jones, William, *34-35*
Joseph, M.T., 127, 128

Kanad, 2, 13, 15
Kapil, 2, 15
Kautilya, 5, 6
Khorana, Hargovind, 97
Kid, James, 46

Kothari, D. S., *97-98*
Krishnan, K. S., 66, 81, *94*

Lafont, Eugene, 53, 60, *67-84*, 8(
Lalla, 11

Macaulay, 41, *42-44*
Mack, John, 39, 40, 47
Mahalanobis, P. C., 98, 120, 121
Mahavira, 11
Mahendralal—*See* Sircar
Mahmud, 22
Manjula, 11
Mansur, 7, 14
Megino, Abbe, 70
Mitra, Rajendralal, 48, 49, *56*, 58, 78
Mitra, S. K., 66
Mohenjo-daro civilisation, 1, 2
Mukherji, Ashutosh, 35, 60, *86*
Mukherji, J. N., 93
Munisvara, 15

Nagarjuna, 7, *14*
Nalanda, 6, 101
National laboratories, 120, 127, 128
Nehru, Jawaharlal, 119, 127, 128, 141
Nilakantha, 15

'Panchasiddhantika', 8
Parasar, 7
Pedler, Alexander, 60, 90
Penaranda, Alphonse de, 60, 76, 84
Prafulla Chandra—*See* Ray
Prthudaka, 11

Ramachandra, 85
Raman, C. V., 65, 66, 74, 81, *93-94*, 97
Ramanujam, Srinivasa, 96
Rammohun—*See* Roy
Ray, Prafulla Chandra, 35, 61, *90-93*, 130
Roxberg, Williams, 46
Roy, Rammohun, 32, 33, 37, *38*

Saha, Meghnad, 66, *95*, 102, 108, 119
Sahni, Birbal, 98
Saif-ud-din Salman, 23
Samarkand astronomy, 15, 23-24 27
Science planning organisations, 143, 144
Scientific policy resolution, 141, 142
Sen, H. K., 92
Shaikh Bu Ali Sina, 22
Siddhantasiromoni, 12
Sikdar, Radhanath, 40
Sine-tables, 9
Sircar, Amritlal, 66
Sircar, Mahendralal, *49-66*, 71-74, 116
Sircar, Sarasilal, 65
Sridhara, 11
Sripati, 11
St. Xavier's College, 67-84
Sudborough, 93
Surya-siddhanta, 8, 9
Susruta, 4, *6*, 7, 40

Tacchini, P., 75
Takshashila, 4, 101
Tata, Jamshedji, 62, 65, 93, 117
Technical education, 48, 58, 59, 91, 92, 120, 121
Temple, Richard, 55, 58, 76
Travers, M. W., 93
'Tuttobodhini Patrika', 49
Tytler, John, 40

Ulugh-beg, 23, 24
University education, 48, 120, 121, 125

Vagbhata, 7
Varahamihira. *8*, 10, 17, 18, 20, 102, 116
Varanasi, 6. 101
Vararuchi, 7
Vedas, 2, 98, 104, 105, 115-118
Vivekananda, Swami, 105, 106, 117, 118

Watson. E. R.. 93

ERRATA

Paje & Line	*In lieu of*	*Read*
p. 7 l. 1.	Charka	Char*a*ka
p. 11 l. 18	equations	equations *of*
p. 14 l. 24	education of science	education *or* science
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p. 137 l. 17	scientific...	scientific kits